DOE/SC-0024
November 20, 2000

CYCLE 19

PROGRAM SOLICITATIONS

SBIR

Small Business Innovation Research

STTR

Small Business Technology Transfer

Closing Date: February 20, 2001

U.S. Department of Energy
Office of Science

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Important Features of this Solicitation, including Changes from Last Year's Solicitation

- **This document contains instructions for submitting grant applications to either or both the SBIR and STTR programs. Provisions that apply exclusively to STTR are distinguished by *italics*.**

- **If the application includes a substantial collaborative effort with a non-profit research institution as a subcontractor, the applicant may request on the cover page that the application be considered in both programs, thereby increasing its chances of winning an award in one of them.**

- **Applicants may select any of the 45 technical topics to apply for SBIR, STTR, or both programs.**

- **Definition of equipment has changed. It is now defined as an article of tangible nonexpendable personal property including exempt property charged directly to the award having a useful life of more than one year and an acquisition cost of $5,000 per unit or more.**

- **As this document went to press, the SBIR program had not yet been reauthorized by the Congress. This reauthorization is expected. However, the ability of the DOE to make Phase I SBIR awards under this solicitation may depend upon the actual enactment of this reauthorization legislation before the FY 2001 grants are selected in June 2001. (Note: The STTR program has already been reauthorized and is not affected by this situation.)**

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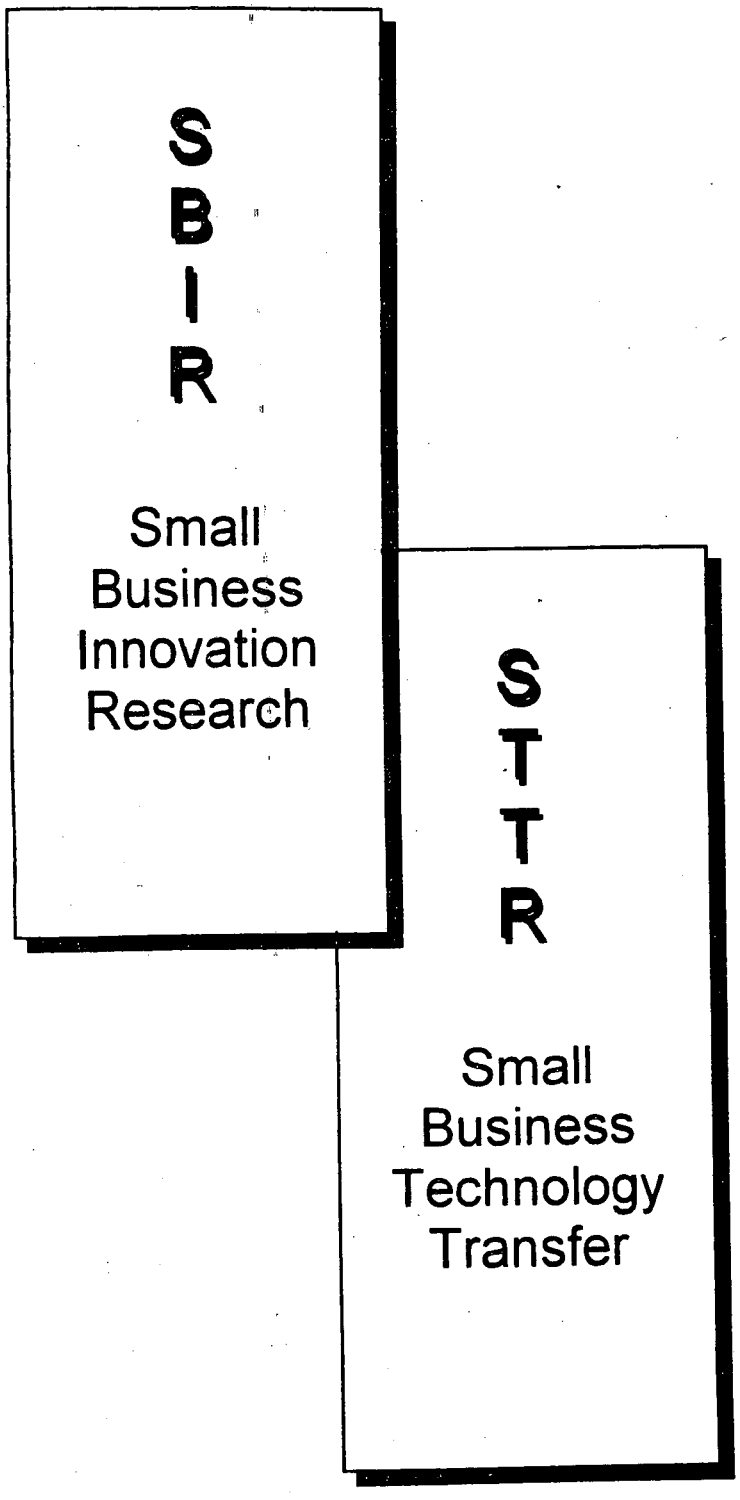

Technical Topic Descriptions

PROGRAM AREA OVERVIEW
OFFICE OF FUSION ENERGY SCIENCES

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The Department of Energy is funding fusion science and technology research as a valuable investment in the clean energy future of this country and the world, as well as to sustain a field of scientific research -- plasma physics -- that is important in its own right and has produced insights and techniques applicable in other fields of science and industry. The mission of the Fusion Energy Sciences (FES) program is to acquire the knowledge base needed for an economically and environmentally attractive fusion energy source. FES research efforts seek to: (1) understand the physics of plasmas, the fourth state of matter -- plasmas constitute most of the visible universe, both stellar and interstellar, and progress in plasma physics has been the prime engine driving progress in fusion research; (2) identify and explore innovative and cost-effective development paths to fusion energy -- the current fusion program encourages research on a wide range of approaches, including the tokamak, the leading power plant candidate, other magnetic configurations, and inertial fusion energy using particle beams or lasers; and (3) explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in a international effort -- reducing costs, avoiding duplication of efforts, and bringing the best available scientific and engineering talent together to seek solutions to complex problems can best be done through the cooperative efforts of the world fusion community.

This is a time of important progress and discovery in fusion research. The FES program is making great progress in understanding turbulent losses of particles and energy across magnetic field lines used to confine fusion fuels, identifying and exploring innovative approaches to fusion power that may lead to more economical power plants, and encouraging private sector interests to apply concepts developed in the fusion research program. It is felt that small businesses, by performing research within the following technical topics, can make significant contributions to these efforts. This solicitation is restricted to science and technology relevant to magnetically confined plasmas and inertial fusion energy. Grant applications pertaining to cold fusion will be declined, as will those related to other fusion energy concepts not based specifically on the use of plasmas for purposes of producing energy/electricity for non-defense purposes.

1. FUSION PLASMA SCIENCE RESEARCH

The Fusion Energy Sciences program currently supports several fusion experiments with many common objectives. These include expanding the scientific understanding of plasma behavior and improving the performance of high temperature plasma for eventual energy production. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts for measuring magnetic plasma parameters, for plasma processing, and for magnetic plasma simulation, control, and data analysis. There is also interest in selected scientific topics with relevance to heavy ion accelerators and heavy ion fusion research. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector.

Grant applications are sought only in the following subtopics:

a. Diagnostics for Magnetic Fusion Plasma Research—Grant applications are sought to develop measurement techniques for parameters such as plasma density, electron and ion temperature, plasma current and current density, plasma position and shape, impurity density, magnetic field strength, ambipolar potentials, and radiation from the plasma. Diagnostics suitable for experimental devices using relatively low magnetic fields or burning plasmas are of particular interest. In addition, methods are desired for examining the edge and divertor regions in tokamak plasmas. Both new techniques and methods to improve the accuracy and resolution of existing diagnostics (e.g., improving the signal-to-noise ratio or extending the range of measured parameters) will be considered. Measurements must be both spatially and temporally resolved for both the absolute values of parameters and for small relative differences. For some of the above parameters, real-time measurements will be an advantage in order to provide for plasma control. For the DIII-D experimental program at General Atomics, diagnostics are needed for: (1) fluctuations of electron and ion temperatures, electron density and electric field, particularly in the high density plasma core (fluctuation frequencies are typically in the range of 100 KHz to several MHz, and fluctuation levels are typically less than 1 percent of the quasi-steady-state

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plasma levels); (2) transport due to fluctuations, which requires cross-correlations between density, temperature and velocity fluctuations; (3) visualization of turbulence in two dimensions, or even three dimensions; and (4) imaging of non-thermal electrons in two dimensions, with energy resolution, if possible. For additional information, see the summary of the February 1998 workshop addressing measurement needs in magnetic fusion devices, listed as one of the references.

Grant applications are also sought to apply diagnostics technology, developed for fusion energy, to the use of plasmas in manufacturing. These grant applications should show how the application of these diagnostics would contribute to the understanding of plasmas used in manufacturing, as well as provide an improved basis for modeling these plasmas.

b. Inertial Fusion Energy—Grant applications are sought for the development of high current, high brightness, ion sources for a heavy ion fusion induction linac. The ion sources must meet the following requirements: (1) beam current of 0.8 A with a normalized emittance < 0.5 π-mm-mrad; (2) pulse length of 20 μs, with < 1 μs rise time; (3) operating duty rate of 10 Hz or less, with long life time ($>10^8$ pulses); (4) the heavy ions (mass 40 amu) can be either singly charged or multiply charged but not in mixed charge states; and (5) the spatial and temporal uniformity of beam intensity should be within ±1 percent.

Related to beam transport and control, grant applications are also sought for: (1) cost-effective devices that use electromagnetic, electrostatic, or plasma techniques to manipulate high intensity, high momentum, multiple parallel heavy ion beams; (2) advanced particle beam diagnostic concepts and devices that provide high speed computer-compatible measurements of particle beam intensity, position, emittance, luminosity, momentum, time of arrival, and energy; and (3) novel, effective techniques to measure the transverse or longitudinal charge distribution in high current heavy ion beams of radius ~1 to 5 cm.

Lastly, a code-development and run-time environment is needed to facilitate advanced code steering for convenient user-programmable, interactive control in accelerator calculations. Grant applications are sought to develop one or more of the following components of the code-development and run-time environment: (1) high level objects for accelerator physics, which would be "known" to the interpreter so as to offer a common interface to disparate codes; (2) intermodule communication methods; (3) automated interpreter linkage to compiled code written in C++, C, and/or Fortran 77/90/95; (4) methods for integrated debugging; and (5) visualization tools for next-generation supercomputers. The system should be based on an existing, free, object-oriented interpreter language that offers dynamic linking for run-time code modification, a numerical analysis package, a GUI (graphical user interface) toolkit, graphics, and self-describing data files (e.g., the Python interpreter meets these criteria). Proposed efforts should seek to build on existing Heavy Ion Fusion accelerator codes capabilities (see reference 4), which incorporate some aspects of code steering, and which may provide a starting point.

c. Plasma Simulation, Control, and Data Analysis—The simulation of fusion plasmas is important to the development of plasma discharge feedback and control techniques. The simulations can be used to make reliable predictions of the performance of proposed feedback and control schemes and to identify those that should be tested experimentally. However, accurate simulations of fusion plasmas are very difficult because of the enormous range of temporal and spatial scales involved in plasma behavior. Considerable progress has been made in recent years in understanding and simulating plasma turbulence along with associated transport, macroscopic equilibrium and stability, and the behavior of the edge plasma. However, there remains a need to integrate the various plasma models. Grant applications are sought to develop computer algorithms applicable to plasma simulations that account for an expanded number of plasma features and an integration of plasma models. Some examples of possible approaches include algorithms that incorporate mathematical techniques such as neural networks, sparse linear solvers, and adaptive meshes; algorithms for coupling disparate time and space scales; efficient methods for facilitating comparison of simulation results with experimental data; and visualization tools for local and remote analysis and presentation of multi-dimensional time dependent data.

Grant applications are also sought to develop software tools useful for the analysis and distribution of fusion data. Areas of interest include methods for coupling codes across architectures and through the Internet; techniques for making highly configurable scientific codes; data management and analysis techniques for large data sets; and remote collaboration tools that enhance the ability of a geographically distributed group of scientists to interact in real-time.

The computer algorithms and programming tools should be developed using modern software techniques and should be

based on the best available models of plasma behavior.

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2. ENABLING TECHNOLOGY FOR FUSION PLASMA EXPERIMENTS

The enabling technology program supports experiments in fusion energy science research related to the production and sustenance of the high temperature plasma. Advanced technologies are needed to better understand the behavior of high temperature plasmas and to improve performance. Hence, the goal of this topic is to develop and demonstrate techniques and instrumentation that will have applications in ongoing fusion-related experimental research. There is also interest in selected technology topics with relevance to different inertial fusion energy driver concepts. It is also expected that concepts developed as part of the fusion research program will have industrial applications in the private sector. **Grant applications are sought only in the following subtopics:**

a. Superconducting Magnets and Materials—New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems; i.e., high field magnets (12 to 20 T) and low loss pulsed magnets. Grant applications are sought for: (1) innovative and advanced materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs; (2) cryogenic superconductor materials with high critical current density, low sensitivity to strain degradation effects, and radiation resistance; (3) novel, low-cost cable designs and fabrication techniques, which minimize conductor strain; (4) superconducting joints for

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high field and pulsed applications; (5) novel, advanced sensors and instrumentation for non-invasively monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); (6) thick (15-30 cm) weldable structural case materials with high strength and toughness at 4 K; (7) welding techniques for such thick cryogenic structural materials; and (8) radiation-resistant electrical insulators (e.g., wrapable inorganic insulators and low viscosity organic insulators, which exhibit low outgassing under irradiation).

b. Components for Plasma Heating and Temperature Profile Control—Two radio frequency heating methods are now extensively used for fusion applications: Ion Cyclotron Resonance Heating, in the frequency range of 50 to 300 MHz, and Electron Cyclotron Resonance Heating, in the frequency range of 100 to 300 GHz. These systems are expected to operate at total power levels of 10 to 50 MW in continuous operation. Grant applications are sought to develop components related to the generation, transmission, and launching of electromagnetic waves in the above frequency range. Components of interest include: (1) power supplies, (2) antenna systems, (3) tuning and matching components, (4) mode converters, windows, output couplers, loads, and diagnostics to evaluate the performance of such components, (5) fault protection devices, which limit tube faults to less than a few joules (e.g., the use of the new high temperature superconducting material to act as a current limiting device), and (6) energy extraction systems from spent electron beams. Grant applications should address the ability of the components to withstand the harsh environment of the fusion research devices.

c. Technology for Inertial Fusion Energy (IFE)—In an inertial fusion power plant, targets must be repetitively injected into a reactor chamber and driven by either a heavy ion beam, a high power laser, or a pulsed power machine (z-pinch or magnetized target fusion). The targets must be fabricated and injected with great precision. Moreover, the target releases a high intensity burst of neutrons, energetic particles, and x-rays that must be contained within the chamber. Grant applications are sought to develop:

(1) Damage resistant chamber materials. The x-rays, neutrons, and particle debris released in inertial fusion have energies up to several MJ/m^2 and are emitted on a time scale from 1 ns to 100 microseconds. Wall materials must survive this environment for periods of up to several years at repetition rates up to 10 Hz. The wall materials must provide low radioactivity under neutron exposure and high temperature operation consistent with efficient power production. Schemes that can protect or shield the first wall are also of interest.

(2) Damage resistant laser optics and optics protection methods for the last optical element before the reactor chamber in a laser fusion system. Both metal mirrors and fused silica windows have been proposed for this "final optic," but other technologies may be appropriate. The final optic must operate at 1/4 to 1/3 micron wavelength and must be protected from exposure or capable of withstanding pulsed irradiation by neutrons, x-rays, and debris. In either approach, the optical elements must survive for several years.

(3) Low-cost fabrication methods for mass-produced inertial fusion energy targets, including targets filled with deuterium-tritium fuel and coated with a protective layer. In an IFE power plant, about 500,000 cryogenic targets must be prepared and injected each day at a rate of 5-10 Hz into a target chamber operating at elevated temperatures. These targets must be precisely made and cost less than $0.30 each.

(4) Methods for target injection and tracking. Targets driven by heavy ion or laser beams must be injected into the chamber at a rate of 5-10 Hz, at velocities from 200 to 400 m/s, and with an acceleration approaching 1000 g. The targets also must be tracked precisely inside the chamber. Gas guns, electrostatic accelerators and electromagnetic accelerators are being evaluated as candidate target injectors. Techniques to accurately track the target (in order to steer them or the driver beams) also are needed.

(5) Efficient procedures for the repetitive replacement of recyclable transmission line (RTL), target assembly, and close-packed coolant. For pulsed-power drivers (z-pinch and magnetized target fusion), the RTL, target assembly, and close-packed coolant (for shock mitigation) must be repetitively replaced on a relatively slow time scale (about 0.1 Hz).

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* See Section 7.1

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3. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION SYSTEMS

An attractive fusion energy source will require the development of technologies and materials that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to assure the safe, reliable, economic, and environmentally benign operation of fusion energy systems. **Grant applications are sought only in the following subtopics:**

a. Structural Materials and Coatings—Grant applications are sought for research that will lead to the relaxation of operating limits by further developing the following materials: (1) vanadium alloy structural materials, (2) silicon carbide/silicon carbide (SiC/SiC) structural composites, (3) oxide dispersion strengthened (ODS) ferritic steels, and (4) electrically insulating coatings to reduce magnetohydrodynamic (MHD) effects in vanadium alloy/liquid lithium systems. For vanadium alloys, areas of interest include the development of improved alloys, increased resistance to degradation under neutron irradiation, relaxation of protection requirements set by their sensitivity to gaseous impurities, and the development of advanced welding/joining techniques to produce tough, ductile vanadium alloy-to-vanadium alloy or vanadium alloy-to-steel joints. For SiC/SiC composites, techniques to improve the thermal conductivity, improved and low cost production methods, and advanced joining processes are needed. For ODS ferritic steels, areas of interest include developing low cost production techniques, product isotropy, and joining methods; these materials would allow for higher temperature service than permitted by the creep strength limits of conventional low activation ferritic steels. For electrically insulating coatings, coating technologies to reduce MHD effects must take into consideration the compatibility with both the coated vanadium alloy and liquid lithium coolant for long time operation at elevated temperatures. In addition, grant applications must address the use of candidate coatings on actual system components and account for the *in situ* repair of defects that could develop in the coating. Note that in this subtopic, the emphasis is on materials for structural applications; issues related to plasma-surface interactions should not be addressed.

b. Free Surface Liquids for Heat Removal—Innovative in-vessel component concepts are desired for heat removal from high power densities (surface heat fluxes at first walls and divertors of about 1 MW/m^2 and 50 MW/m^2, respectively) with good safety, reliability, and maintenance features. Current interests are focused on evaluating the use of flowing liquid metals with direct exposure to the plasma. Candidate liquids metals include lithium, tin-lithium, tin, gallium, and lead-lithium. Also, lithium-beryllium fluoride salts are of interest for surface heat fluxes up to 2 MW/m^2. Grant applications are sought to develop: (1) techniques for the removal of significant heat loads (at least 1 MW/m^2) by free surface flowing liquids (proposed techniques should address the effect of magnetohydrodynamics on heat transfer and should also consider heat removal enhancement techniques, such as turbulence promoters), (2) efficient nonlinear solution methods, as well as alternate object-oriented languages for computational tools, to model fusion-relevant issues of liquid wall flows (such as heat transfer at free surfaces and free flows with magnetohydrodynamic effects and turbulence), (3) techniques to suppress surface vaporization, such as the addition of alloying materials, (4) nozzles for liquid injection (e.g., streams, jets, films, and droplets) and collection/removal techniques that are drip and splash free, self-cooling, and efficient in head recovery at the outlet, and (5) non-invasive diagnostics for experiments to study high temperature free surface liquid flows in magnetic fields (such diagnostics might include measurements of mean flow velocity, turbulence intensity, velocity fluctuations, flow depth, and surface/depth temperature profiles).

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7. U.S. DOE Fusion Energy Sciences Program http://wwwofe.er.doe.gov/

PROGRAM AREA OVERVIEW
HIGH ENERGY PHYSICS

http://www.er.doe.gov/production/henp

Through fundamental research, scientists have found that all physical matter is composed of apparently point-like particles, called leptons and quarks. These constituents of matter were created at the "big-bang" which originated our universe and they are components of every object that exists today. We also understand a great deal about the four basic forces of nature which we experience: electromagnetism, the strong-nuclear force, the weak force, and gravity. We have recently learned that the electromagnetic and weak forces are two components of a single force, called the electro-weak force. This is analogous to the conceptual unification in the mid-nineteenth century of the electric and magnetic forces into the theory of electromagnetism. History shows that, over a period of many years, the understanding of electromagnetism has led to many practical applications that form the technical basis of modern society.

The goal of the Department's High Energy Physics (HEP) program, is to provide mankind with new insights into the fundamental nature of energy and matter and the forces that control them. This program is a major component of the Department's fundamental research mission. Such fundamental research provides the necessary foundation that enables the nation to progress in its science and technology capabilities, to advance its industrial competitiveness, and to discover new and innovative approaches to our energy future.

Experimental research in HEP is primarily performed by university scientists using particle accelerators located at major laboratories in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago, IL and the Stanford Linear Accelerator Center (SLAC) near San Francisco, CA. Further, the Department is finalizing arrangements for a significant role in the Large Hadron Collider project at the CERN laboratory in Switzerland. The Tevatron at Fermilab is currently the world's highest energy accelerator. SLAC also provides unique experimental capabilities.

While much progress has been made during the past three decades in our understanding of particle physics, future progress depends on the availability of new state-of-the-art technology for accelerators, colliders, and detectors operating at the high energy and/or high intensity frontiers.

Within High Energy Physics, the High Energy Technology subprogram supports the research and development required to extend relevant areas of technology in order to support the operations of highly specialized accelerators, colliding beam facilities, and detector facilities which are essential to the goals of the overall High Energy Physics program. The Department of Energy SBIR program provides a focused opportunity and mechanism for small businesses to contribute new ideas and new technologies to the pool of knowledge and technical capabilities required for continued progress in high energy physics research, and to turn these novel ideas and technologies into new business ventures. The technical topics that follow include four accelerator-related topics and two detector-related topics.

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4. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The Department of Energy (DOE) High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in the following areas: (1) new concepts for acceleration, (2) novel device and instrumentation development, (3) inexpensive electron sources, and (4) computer software that will contribute to overall advances in accelerator technology applicable to the High Energy Physics program. Relevance to applications in high energy physics must be explicitly described. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 10. Grant applications which propose using resources of a third party (such as a DOE Laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. New Concepts for Acceleration—Grant applications are sought to develop new or improved acceleration concepts. Designs should provide very high gradient (>100 MeV/m for electrons or >10 MeV/m for protons) acceleration of intense bunches of particles, or efficient acceleration of intense (>50 mA) low energy (of order <20 MeV) proton beams. One possible concept might include the fabrication of accelerator structures from materials such as Si or SiO_2, using integrated circuit technology; in this case, power sources might include lasers in the wavelength range from 1 to 2.5 micrometers. For all proposed concepts, stageability, beam stability, manufacturability, and high wall plug-to-beam power efficiency must be addressed in detail. Grant applications must also address the marketability of any systems, technologies, and devices to be developed.

b. Novel Device and Instrumentation Development—Grant applications are also sought for the development of electromagnetic, permanent magnet, or silicon microcircuit-based charged particle optical elements for particle beam focusing. Examples include, but are not limited to, dipoles, quadrupoles, higher order multipole correctors for use in electron linear accelerators, and solenoids for use in electron-beam or ion-beam sources or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.1 to 10 cm. In these optical elements, permanent magnets or hybrid magnets incorporating magnetic materials that have very high residual magnetization, radiation resistance, and thermal stability (low variation of field strength with temperature) are of particular interest. Also of interest are field probes for measuring silicon microcircuits with effective apertures down to 5 micrometers.

Grant applications are also sought for: (1) novel charged particle beam monitors to measure the transverse or longitudinal charge distribution or emittance, or phase-space distributions of small radius (0.1 micrometers to 5 millimeters diameter), short length (10 micrometers to 10 millimeters) relativistic electron or ion beams; (2) devices capable of measuring and recording the Schottky or transition radiation spectrum of these beams (proposed techniques should be nondestructive or minimally perturbative to the beams monitored and have computer-compatible readouts); and (3) lasers for laser-accelerator applications which provide substantial improvements over currently available lasers in one or more of the following: longer wavelengths (2 to 2.5 micrometers for use with Si transmissive optics), higher power, higher repetition rates or shorter pulse widths.

Grant applications are also sought for the development of novel devices and instrumentation for use in the cooling (transverse and longitudinal emittance reduction) of muon beams. Approaches of interest include the development of: concepts or devices for ionization cooling, including emittance exchange processes; instrumentation for muon cooling channels with muon intensities of 10^{12} muons/pulse; or fast (of order 10 picosecond) timing detectors for muon cooling experiments with low muon intensity (of order 10^5 muons/second).

c. Inexpensive high quality electron sources—Grant applications are sought for the design and prototype fabrication of small, inexpensive (<$1 million) electron sources for use in advanced accelerator R&D laboratory experiments. The following parameters are target values for accelerator research experiments: (1) energy range of 5 to 35 MeV providing, at a minimum, on the order of 10^9 electrons in a bunch less than 5 picoseconds long; (2) normalized transverse beam emittance less than or equal to 5 pi mm-mrad; and (3) pulse repetition rate greater than 10 Hz. Grant applications are also sought for significantly lower bunch charges, energies, and emittances but with comparable or greater peak currents and significantly higher repetition rates for bunches from a matrix cathode.

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Grant applications are sought for the development of radio frequency photocathodes (robust, with quantum efficiencies >0.1 percent) or other novel rf gun technologies operating at output electron beam energies >3 MeV. Laser or electron driven systems for such guns are also sought.

Cathodes are needed for vacuum-electronic devices such as klystrons, gyrotrons, and high brightness electron sources for accelerators. Currently, they have many limitations: conventional thermionic cathodes are limited to about 10 amps/cm^2; reservoir cathodes can operate at higher temperatures and can deliver up to 40 amps/cm^2, but may have life limited by the build-up of deposits from the evaporated barium oxide; photocathodes require expensive lasers, and plasma cathodes have limited life. Therefore, grant applications are sought for research and development leading to rugged, long-life cathodes or electron guns that are capable of producing current densities and currents (several hundred amperes pulsed) comparable to or greater than thermionic emission devices. Applications must focus on one of the following areas of interest: (1) use of secondary emission to amplify a lower current density beam to generate a higher density one, (2) arrays of field emission needles or knife edges (these have been studied extensively but are still easy to damage and hard to use), (3) hybrid, laser-assisted and gated matrix cathodes using back illumination with lasers whose output matches the emitter array, (4) use of field emission from diamond films or other surfaces at higher pulsed fields (flat diamond films have been found to yield significant current densities with relatively low fields), (5) use of ferroelectric cathodes, or (6) new methods for bonding evaporated barium oxide in reservoir cathodes -- because evaporated material sometimes peels off and causes breakdown, improved bonding could increase the lifetime of devices using such cathodes.

Grant applications are also sought to develop a sheet-beam, gridded, thermionic, dispenser-cathode gun for use in a 250 kV, 80 MW X-band (11.4 GHz), sheet-beam klystron. Parameters of the cathode are 100 cm^2 of cathode area, cylindrical or flat geometry, aspect ratio (cylinder length to segment width) of 2:1, and cathode current loading of 5 A/cm^2. Grantees will work closely with engineers in the SLAC Klystron Department to match cathode design with klystron parameters. A gridded, short-pulse klystron may provide an alternative to a pulse compression system, such as for a linear collider.

Lastly, grant applications are sought for research and development on gated electron sources with pulses or pulse trains larger than 0.1 microsecond at about 100-200 pulses per second, and on semiconductor photocathode sources of electrons with polarization in the range of 80 percent and energy in the range of a few volts to several hundred kilovolts. In addition, intensity stability <1 percent is required for polarized beams in pulsed linacs.

d. Computer software—Grant applications are solicited for developing new or improved computer software specifically for the design or study of charged particle beam optical systems, accelerator systems, or accelerator components. Such applications should incorporate the innovative development of user-friendly interfaces with emphasis on graphical user interfaces and windows. Grant applications are also solicited for the conversion of existing codes to incorporate such interfaces, provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate.

Grant applications are also sought for improved software for command and control functions, real time database management, and status display systems encountered in state-of-the-art approaches to accelerator control.

In addition, grant applications are sought for improved management of integrated cost, schedule, and resource database information for planning and control of large High Energy Physics program R&D and construction projects, such as the Next Linear Collider.

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5. RADIO FREQUENCY ACCELERATOR TECHNOLOGY FOR HIGH ENERGY ACCELERATORS AND COLLIDERS

The Department of Energy (DOE) High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in (1) high gradient accelerator structures, (2) high peak power radio frequency (rf) technologies, and (3) new concepts for low-cost, very efficient, pulse power modulators. Relevance to applications in high energy physics must be explicitly described.

Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 10. Grant applications that propose using resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. Radio Frequency Acceleration Structures—Grant applications are sought for research on very high gradient rf accelerating structures, normal or superconducting, for use in

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accelerators and storage rings. Gradients >100 MeV/m for electrons and >10 MeV/m for protons in normal cavities are of particular interest, as are means for suppressing unwanted higher-order modes and reducing costs. Grant applications that address recent problems of voltage breakdown in long structures, especially, especially at 11.4 GHz, are particularly desirable. Means for achieving unloaded voltage gradients >20 MeV/m and reducing costs in superconducting cavities are also of interest, as are methods for reducing surface breakdown and multipactoring (such as surface coatings or special geometries) and for suppressing unwanted higher order modes. Grant applications should be applicable to devices operating at wavelengths from 1.2 to 100 GHz.

b. Radio Frequency Power for Linear Accelerators—Grant applications are sought for new concepts, high-power rf components, and instrumentation for producing high peak power (>50 MW at 10 GHz, appropriately reduced when scaled to higher frequencies), narrow band, low duty-cycle, low pulse repetition frequency (approximately 0.1 to 1 kHz) pulsed rf amplifiers for application to upgrading future large electron/positron linear colliders. Potential electrical efficiencies greater than 45 percent are considered essential. Innovation related to cost saving, manufacturability, and electrical efficiency is especially sought. Some examples follow:

(1) One way of providing rf power is the cluster klystron, a device consisting of a "cluster" of separate magnetron gun driven klystrons that share a common focusing field and accelerating gap. Such a device could give high total pulsed power with relatively small individual beam currents, and thus be capable of high efficiency. The use of magnetron guns allows the many beams to be enclosed in a compact space, and have modulation anodes that allow the current to be switched, thus eliminating the need for a pulsed high-voltage modulator. Therefore, grant applications are sought to develop cluster klystrons, as well as highly stable magnetron guns for cluster klystrons.

(2) Another device for providing high rf power is the co-axial gyroklystron under development at University of Maryland (UMD). It has an input frequency of 8.57 GHz and output frequency of 17.14 GHz. This microwave amplifier requires a Magnetron Injection Gun (MIG), (500 kV, 800 A, pulse duration of 2 microseconds, pulse repetition frequency < 60 Hz) to produce an annular beam of spiraling electrons. Parameters of this beam are: transverse/axial electron velocity ratio variable between 1.0 and 1.5, axial velocity spread less than 5%, average electron beam radius of 2.38 cm, and beam thickness of 1 cm. R&D is required to improve the uniformity of electron emission from the annular cathode emitter, and to improve high voltage standoff of the electron gun insulator. Therefore, grant applications are sought to develop MIG cathode structures, single or segmented, for a MIG-type electron gun meeting these needs, or to develop the whole gun structure including the gun optics and high-voltage ceramic insulator design. The gun must operate in high vacuum conditions, 10^{-8} Torr or less, and be designed so it is not a source of gas in this pressure range. Proposed projects should include a broad study of emitter fabrication including segmented emitters and emitter lifetime and should include modeling of all aspects of MIG operation, along with the development and fabrication of a state-of-the-art MIG to mate with UMD microwave structures. Grantees will work closely with faculty at the UMD to match this MIG design to gyroklystron parameters. Futher information on the MIG can be obtained from Professor Wesley Lawson at UMD (email: lawson@eng.umd.edu; phone: 301-405-4972; fax: 301-314-9437).

Upgrades to the next generation linear collider will require many rf power handling components which are not presently available, e.g., rf windows, couplers, mode transformers, rf loads, and high power rings capable of operating at high pulse powers (20 - 100 MW), high frequencies (11 - 100 GHz), and pulse lengths of several microseconds. Grant applications are sought for passive and active rf components such as over-moded mode converters from rectangular to circular waveguide, high-power rf windows, circulators, isolaters, switches, and high-power rf pulse compression methods for use in future linear colliders.

Lastly, grant applications are sought for: (1) higher efficiency rf sources working around 1.3 GHz with power levels up to 50 MW and pulse width of a few hundred microseconds with applicability to two-beam accelerators; and (2) higher efficiency (>65 percent) 1.0 GHz or higher frequency sources appropriate for a superconducting-rf option for a linear collider—such sources should provide a few MW of power, 2-10 milliseconds pulse length, and 5-100 Hz repetition rate (includes continuous wave).

c. New Concepts for Pulsed Power Modulator—Most rf power sources for future linear colliders require high peak-power pulse modulators of considerably higher efficiency than presently available. Grant applications are sought for new types of modulators in the 400 kV - 1 MV range for driving currents of 400 - 800 A, with pulse lengths of 0.2 - 2 microseconds, and rise- and fall-times of less than 0.2 microsecond. Innovation related to cost saving,

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manufacturability, and electrical efficiency in modulators is especially important. Modulators with improved voltage control for rf phase stability in some alternate rf power systems are also sought.

Grant applications are also sought to develop high power solid state switches, either Insulated Gate Bipolar Transistors (IGBTs) or Thyristors, for pulse power switching. Requirements include the ability to switch high current pulses (2-5 kAmps) at voltage levels of 2 to 6 kV with switching times of less than 300 nsec. Construction and low inductance packaging techniques must be developed to allow current state-of-the-art chip designs to handle very high di/dt (20 kAmps/μs) at low duty cycle (<0.1%).

Lastly, grant applications are sought to develop and optimize high reliability, high energy density energy storage capacitors for solid state pulse power systems. The capacitors must: (1) deliver high peak pulse current (5 - 8 kAmps) in the partial discharge region (less than 10 percent voltage droop during pulse), (2) be designed with very low inductance connections to allow fast rise and fall time discharge without ringing (di/dt ~ 20 kAmps/μs), and (3) be packaged to meet the requirements of high power solid state board layouts and have minimum production cost.

Note: Grant applications for components and systems which target the presently envisioned Next Linear Collider should be submitted under Topic 7.

d. Radio Frequency Power for Muon Colliders—Grant applications are sought for new concepts, approaches, or designs for radio frequency amplifiers or pulse compression schemes for use in the acceleration and ionization cooling channels of a future muon collider. The amplifiers or compressors must have high peak power (>50 MW), and pulsed, low frequency (in the range 2 millisecond pulses at 20 MHz to 0.1 millisecond pulses at 200 MHz). There is also interest in higher power (>100 MW) pulsed sources at higher frequencies (in the range 30 microseconds at 400 MHz to 10 microseconds at 800 MHz). All muon collider amplifiers must have moderate repetition rate capability (e.g., 15 Hz). Cost per unit of peak power, including that of the needed power supplies, is of particular interest.

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6. HIGH-FIELD SUPERCONDUCTOR AND SUPERCONDUCTING MAGNET TECHNOLOGIES FOR HIGH ENERGY PARTICLE COLLIDERS

The Department of Energy High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in (1) high-field superconductor and (2) superconducting magnet technologies. This topic addresses only those superconductor and superconducting magnet development technologies that support dipoles, quadrupoles, and higher order multipole corrector magnets for use in accelerators, storage rings, and charged particle beam transport systems. Relevance to applications in high energy physics must be explicitly described and will be a factor in the application selection process. Grant applications which propose using resources of a third party (such as a DOE laboratory) must include in the application a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. High-Field Superconductor Technology—Grant applications are sought for new or improved materials, starting raw materials, and related processing techniques for high critical-current, high critical-field conductors to produce low alternating current (AC) loss conductors for use in very high-field magnets. While improvements are sought for magnets above 8 Tesla, the engineering goal for the near future (7 to 10 years) is at least 15 Tesla. Applications must demonstrate such property improvements as higher critical-current densities and higher critical fields, as well as manageable degradation of these properties as a function of applied strain. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K. Process improvements must result in equivalent performance at reduced cost. Advanced conductor fabrication techniques of interest also include methods to utilize high aspect ratio stranded conductors or tape geometries in particle accelerator applications. Materials of interest include: niobium-titanium, ternary niobium-titanium alloys, the so-called "A-15" compounds (e.g., niobium-tin and niobium-aluminum), and oxide (high temperature) superconductors. Regarding oxide superconductors, a minimum current density of 1200 A/mm^2 (not cm^2) in the superconductor itself and a minimum current density of 250 A/mm^2 over a total conductor cross section, at 12 Tesla minimum and 4.2 K, must be achieved. All grant applications for A-15 and oxide superconductors must address the challenge of long length, large volume industrial production for practical applications. The details of such production plans, including expected development time, also must be discussed. Proposals addressing improvement of starting raw materials are encouraged.

High performance niobium-titanium (NbTi) alloys operating above 8 Tesla appear to be required for focusing quadrupole magnets or for "low field" graded windings in higher field dipoles. Grant applications are sought for NbTi composite superconductors whose properties are optimized at the higher field portion of the short sample curve. Grant applications must focus on conductors that will be acceptable for accelerator magnets.

In addition, grant applications are sought for innovative insulating materials which would enable employment of new superconductors, such as the A-15 or oxide types, in practical devices. Insulating materials must be compatible with high temperature reactions in the 750-900°C range and must be capable of supporting high mechanical loads at cryogenic temperatures.

b. Superconducting Magnet Technology—Grant applications are sought to develop: (1) improved instrumentation to measure properties (such as local strain, temperature, and magnetic field) which are directly applicable to the testing of superconducting magnets; (2)

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improved current leads based on high-temperature superconductors for application to high-field accelerator magnets, which have requirements that include current level at 5 kA or greater, stability, low heat leak, and good quench performance; (3) alternative designs, to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets, that may be more compatible with the more fragile A-15 and the oxide, high-field superconductors; or (4) designs for bent (e.g., bending radius of 0.5 meter) solenoids (e.g., 4 T, 30 cm inside diameter) with superimposed dipole fields (e.g., 1 T) for dispersion generation in large emittance beams.

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7. TECHNOLOGIES FOR THE NEXT-GENERATION ELECTRON-POSITRON LINEAR COLLIDER

The DOE High Energy Physics program supports research and development (R&D) of technologies for a TeV-scale electron-positron linear collider that would use normal-conducting X-Band (11.4 GHz) microwave power. This collider will be five to ten times the energy of present-generation linear accelerators. This topic addresses near-to-medium term developments to enhance performance and reliability and/or to reduce costs of accelerator components and infrastructures. Applications should demonstrate relevance to these issues. Any letters included in an application which indicate the use of resources of a third party (such as a DOE Laboratory) must include certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. Direct Current (DC) and Pulsed Power Supplies, Modulators and Components—Advances are needed in various aspects of pulse modulators and associated components to drive klystrons in both injector and main linac applications. Grant applications are sought for:

(1) DC Power Supplies operating at 2 to 5 kV from about 50 to 500 kW output, to drive capacitor banks in IGBT (Insulated Gate Bipolar Transistor) switched induction modulators or Marx generators. The power supplies must have 0.1 percent regulation, withstand pulsed current duty cycle between short discharges (3 - 6 microseconds) and recharge at 120-180 Hz steady state. Operation for shorter pulses at higher recharge rates is also desired for testing purposes. Other objectives include high reliability, low cost, and efficiency greater than 90 percent.

(2) Ultra-Reliable Capacitors of ~10-25 microfarads at 2.5 to ~6 kV to provide stored energy for partial discharge, on-off switch modulator configurations. Requirements include low loss, low inductance, high power density to minimize volume, MTBF >100,000 hours, and low cost. Long lifetime is a priority because the large numbers of such units in the modulator designs will dominate modulator reliability.

(3) High Voltage Pulse Transformers with ratios from 1:6 up to 1:15, with low leakage inductance and minimized core loss, for use in solid-state-switch driven modulators with a load-matching transformer. The modulators will drive a pair of X-band klystrons at 180 Hz with ~500 kV, 520 A peak and 3 microseconds pulse-length, or drive an S-band klystron

in the injector at 180 Hz with 380 kV, 800 A peak, and at least 6 (possibly up to 16) microseconds pulse-length. Rise/fall times of less than 300 ns and droop/ripple of less than 2 percent are desired. Transformers must operate in oil and be compact, efficient, and cost-effective to manufacture.

Further information on this subtopic can be obtained from Ray Larsen at SLAC (email: larsen@SLAC.Stanford.EDU; phone: 650-926-4907; fax: 650-926-5124).

b. Manufacturing Processes and Support Technology for Microwave Power—The transmission of high power, X-band microwaves to the high-energy, X-band linear accelerators in the NLC may utilize oversized, multi-mode components and waveguides with non-standard cross sections, evacuated to 10 nTorr pressure. Components for such functions as manipulating microwave modes or introducing mechanical flexibility may be irregularly shaped. They also require demanding tolerances on internal dimensions (mils), surface finishes (microns), leak rates (10^{-12} Torr-liter/sec/cm^2), rf voltage hold-off (40 MV per meter), and surface conductivity (at least as good as aluminum). For these components, conventional manufacturing processes such as investment casting or electroforming are not adequate. Therefore, grant applications are sought to develop appropriate techniques or manufacturing processes to economically produce these microwave components in large batches of identical parts.

Grant applications are also sought to develop or advance net shape or near net shape manufacturing processes for mass production of high-conductivity (100 percent dense), oxygen-free (ASTM F.68 Metallographic Class I) copper components used in ultra-high vacuum (UHV) (equilibrium vapor pressure <1 nTorr at 300°C), high-power microwave applications. Mechanical tolerances of 50-100 micrometers must be achieved. Grant applications are also sought to develop or advance processes for precision machining subsequent to the aforementioned net shaping, with dimensional and flatness tolerances of one micrometer and surface finishes of 10 nanometer (rms). All grant applications, whether addressing net shaping or precision machining, must demonstrate significant cost reduction over current numerically controlled machining methods. Manufacturing processes with similar tolerances and applicability for the mass production of UHV, high-power parts made from stainless steel, aluminum, or copper alloys are also of interest.

Lastly, to support the generation and transmission of high power microwaves, grant applications are sought to develop: (1) a microwave circulator and/or active switch with high efficiency for multi-megawatt power levels at 11.4 GHz (see reference 7); (2) robust, reliable techniques for distributed pumping and/or for suppression of surface field emission in components and waveguides; (3) robust, reliable techniques for the joining components and waveguide sections in the accelerator housing (see reference 7); or (4) new permanent magnet focusing structures with reduced cost or improved reliability for X-, S-, or L–band "SLAC-type" klystrons.

Further information on this subtopic can be obtained from John Cornuelle at SLAC (email: johnc@SLAC.Stanford.EDU; phone: 650-926-2545; fax: 650-926-5124).

c. UHV Manufacturing Techniques for NLC Damping Ring Cavities and Vacuum Chambers—Grant applications are sought to develop ultra-high vacuum (UHV) manufacturing techniques for low-cost, reliable fabrication of UHF-band radiofrequency accelerating cavities with damped higher-order modes for use in damping rings. Fabrication of the cavity and its penetrations has in the past been performed by multi-axis milling of oxygen-free, high-conductivity copper — an expensive process. More cost-effective candidate techniques include stereolithography, casting, electroforming, plunge-EDM, etc. Methods are also required for providing cooling channels that can be accessed from the exterior of the cavity. Methods such as plasma deposition over machined or formed channels, or brazed tubing, may be investigated (in preference to existing electroplating techniques). The joining of parts by electron-beam welding is also of interest.

Grant applications are also sought to develop improved low-cost techniques for the fabrication of damping-ring UHV aluminum vacuum chambers with detailed, non-circular cross-sections and outgassing rates of 10^{-12} Torr-liter/sec/cm^2 or less at room temperature. Machining tolerances are generally approximately ± 1 mm over the length of the structure, with detailed features requiring tolerances of approximately ±100 micrometer to be added in a subsequent process. In order to reduce the effective surface area, and thus outgassing rate, the chambers may be extruded, with a final machined surface finish. Other details of the manufacturing process, such as the cleaning process and the choice of machining lubricant are also critical in producing and maintaining low outgassing rates. Other needs include (1) improved methods of joining the vacuum chambers to the stainless steel flanges with UHV-compatible techniques, and (2) the development of a method and equipment to directly measure outgassing rates, in order to evaluate the chamber

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manufacturing techniques described above. For the latter, requirements include measurements of 10^{-12} Torr-liter/sec/cm^2 or less at room temperature for multiple samples of aluminum or other metals, and minimal sample sizes to lower the costs of preparation.

Further information on this subtopic can be obtained from John Corlett at the Lawrence Berkeley National Laboratory (email: JNCorlett@lbl.gov; phone: 510-486-5228; fax: 510-486-7981).

d. Focusing and Auxiliary Systems—As a potentially more economical and reliable alternative to DC electromagnets, permanent magnets are under consideration for about half of the 6000 beam-line magnets in the NLC. Grant applications are sought for the development of a highly reliable permanent magnet quadrupole that is remotely tunable over a range of ±20% relative to its nominal integrated focusing gradient (taking about 10 seconds). The quadrupole must be magnetically stable, with less than 1.4 micrometers of magnetic center shift. These specifications require symmetry and stability not previously sought from permanent magnets and greatly influence the magnetic and mechanical design of the quadrupole. A typical quadrupole will have 13-mm-diameter aperture, 430-mm length, and 0.8-Tesla pole-tip field. The operating environment that is contemplated is 10,000 Rads per year, and stable temperature near 90°F. See reference 1 for more information on this subject.

Grant applications are also sought to develop a translational mover system for an electromagnet in an accelerator beam line. The mover should be capable of repositioning, horizontally and vertically, a 700-kg load in 50-nm steps over a range of ±3 mm, with average speed of 5 micrometers/sec. The resonant vibration frequency of the magnet-mover system should exceed 20 Hz.

In order to ensure stable collisions of nanometer-size NLC beams, the relative and absolute motion of the final focussing magnetic lenses, which are separated by 6-8 meters, must be suppressed to less than or approximately 1 nm amplitude at frequencies above 5 Hz. Therefore, grant applications are sought to develop techniques and components of a new vibration suppression system. With sub-nanometer accuracy in the frequency range above a few Hz, it must be capable of sensing and suppressing relative and absolute motion of long, separated massive objects. The objects may reside in a 3-6 T external magnetic field from the solenoid of the high energy physics detector. The separated objects may be either: (1) 0.5 ton, 3-m long, electromagnetic or permanent magnet quadrupoles at room temperature, or (2) less massive, 5 cm diameter, 3-m long, cold metal bores of superconducting quadrupoles to be stabilized inside their cryostats.

Finally, sensors and electronic devices are needed for the measurement and control of key NLC features. Grant applications are sought to develop: (1) robust, non-contact position sensors based on radiation resistant materials (e.g. eddy-current sensors) and produced at low cost in large quantities -- the critical range of motion is ~1 mm with resolution and repeatability of ~100 nm; and (2) custom integrated electronic circuits that can be ported to a radiation-hard process for use in an accelerator housing -- specifically, circuits are needed for control of: beam position monitors; ion-pump controllers; low-level rf mixers, demodulators, multiplexers and digitizers; and magnet-mover controllers.

For this subtopic, further information on the first two paragraphs above can be obtained from John Cornuelle at SLAC (e-mail: johnc@SLAC.Stanford.EDU; phone: 650-926-2545; fax: 650-926-5124). For the third paragraph above, further information can be obtained from Andrei Seryi at SLAC (e-mail: seryi@SLAC.Stanford.EDU; phone: 650-926-4805; fax: 650-926-5124). For the last paragraph, further information can be obtained from Ray Larson at SLAC (e-mail: larsen@SLAC.Stanford.EDU; phone: 650-926-4907; fax: 650-926-5124).

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* See Section 7.1

8. HIGH ENERGY PHYSICS DETECTORS

The Department of Energy (DOE) supports research and development in a wide range of technologies essential to experiments in high energy physics and to the accelerators at DOE high energy accelerator laboratories. The development of advanced technologies for particle detection and identification for use in high energy physics experiments or particle accelerators is desired. Principal areas of interest include particle detectors based on new techniques and technological developments (e.g., superconductivity or solid-state devices) or detectors which can be used in novel ways as a consequence of associated technological developments in electronics (e.g., sensitivity or bandwidth), with particular interest in devices exhibiting insensitivity to very high radiation levels. Also of interest are novel experimental systems that use new detectors or use old ones in new ways that either extend basic high energy physics experimental research capabilities or result in less costly and less complex apparatus. **Grant applications must clearly and specifically indicate their particular relevance to high energy physics programmatic activities.**

Although particle physics detector development is often concentrated at major national particle accelerator centers, there are many developmental endeavors, especially in collaborative efforts, where small businesses can make creative and innovative contributions that further develop the required advanced technologies. Nonetheless, applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available at http://www.hep.net/sites/directories.html. **Grant applications are sought only in the following subtopics:**

a. Particle Detection and Identification Devices—Grant applications are sought for novel devices in the areas of charged and neutral particle detection and identification. Examples include, but are not limited to, semiconductor particle detectors (silicon, CVD diamond, or other semiconductors), light-emitting particle detectors (scintillating materials including fibers and crystals or Cherenkov radiators), photosensitive detectors that could be used with light-emitting detectors (photomultipliers, micro-channel plates, photosensitive semiconductors), gas or liquid-filled chambers (used for particle tracking or in electromagnetic or hadronic calorimeters, Cherenkov or transition radiation detectors). The proposed devices must be explicitly related to future high-energy physics experiments, either accelerator or non-accelerator based, or to future uses in particle accelerators. Relevant potential improvements over existing devices and techniques must be discussed explicitly (e.g., radiation hardness, energy, position, and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, cost).

b. Detector Support and Integration Components—High energy physics experiments frequently require high performance detector support that will not compromise the precision of the detectors. Therefore, grant applications are sought for components used to support or integrate detectors into high-energy physics experiments. The support components must be well matched to the detectors and possess some or all of the following features: low mass, high strength or stiffness, low intrinsic radioactivity, exceptionally high or exceptionally low thermal conductivity, and low cost.

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Grant applications are also sought for alignment and cooling systems.

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9. HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

The Department of Energy supports the development of advanced electronics and computational technologies for the recording, processing, storage, distribution, and analysis of experimental data that is essential to experiments and particle accelerators used for high energy physics research. Areas of present interest include event triggering, data acquisition, scalable clustered computers systems, distributed collaborative infrastructure, distributed data management and analysis frameworks, and distributed software development useful to high energy physics experiments and particle accelerators. **Grant applications must clearly and specifically indicate their relevance to present or future high energy physics programmatic activities.**

Although particle physics detector instrumentation, data processing and analysis, and software development typically occur in large collaborative efforts at national particle accelerator centers, there are efforts where small businesses can make innovative and creative contributions to the further development of the required advanced technologies. Applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available by institution at http://www.hep.net/sites/directories.html. Grant applications which propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. High-Speed Electronic Instrumentation—Grant applications are sought to develop components, electronics, systems, and instrumentation modules as follows:

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(1) Special purpose chips and devices are sought for use in the internal circuitry employed in large particle detectors. Desirable features include low noise, low power consumption, high packing density, radiation resistance, very high response speed, and/or high adaptability to situations requiring multiple parallel channels. Desirable functions include amplifiers, counters, analog pulse storage devices, decoders, encoders, analog-to-digital converters, controllers, and communications interface devices.

(2) Circuits and systems are sought for rapidly processing data from particle detectors such as proportional wire chambers, scintillation counters, silicon microstrip detectors, particle calorimeters, and Cerenkov counters. Representative processing functions and circuits include low noise pulse amplifiers and preamplifiers, high speed counters (>300 MHz), and time-to-amplitude converters. Compatibility with one of the widely used module interconnection standards (e.g., FASTBUS, or VMEbus) is highly desirable, as would be low power consumption, high component density, and/or adaptability to large numbers of multiple channels.

(3) Advanced, high speed logic arrays and microprocessor systems are sought for fast event identification, event trigger generation, and data processing with very high throughput capability. Such systems should be compatible with or implemented in one of the widely used module interconnection standards (e.g., FASTBUS, or VMEbus).

(4) Much of the electronics instrumentation in use in high energy physics is packaged in one of the international module inter-connection standards (e.g., FASTBUS, or VMEbus). Therefore, grant applications are sought for modules that will provide capabilities not previously available, for substantial performance enhancement to existing types of modules, and for components, devices, or systems that will enhance or significantly extend the capability or functionality of one of the standard systems. Examples include large and/or fast buffer memories, single module computer systems (either general purpose or special purpose), display modules, interconnection systems, communication modules and systems, and disk-drive interface modules.

b. Large Scale Analysis Computer Systems—Grant applications are sought to develop: (1) computer system components and supporting software enabling large scale and open use of storage networks, especially for magnetic disks, optical disks, and magnetic tapes; (2) computer system components and supporting software enabling the use of TCP/IP protocols in a more efficient manner over a local area network; (3) computer software or systems for monitoring and operating heterogeneous computer systems and networks for functionality, performance, and manageability criteria (also, ease of software installation on hundreds of computers would be desired); (4) methods for integrating distributed authority and access control into distributed data systems; and/or (5) improvements to the quality, reliability and cost effectiveness of petabyte storage systems. Proposed efforts must address identified computing problems related to diverse, large scale computing systems that support particle physics analysis.

c. Distributed Collaborative Infrastructure and Distributed Data Management and Analysis Frameworks—Advanced computational tools and software are needed to strengthen the ability of dispersed particle physics researchers to collaborate and to address problems related to the acquisition, handling, storage, analysis, and visualization of large datasets by these distributed collaborations. Grant applications are sought to develop: (1) client-server frameworks and Web tools for creating collaborative environments, facilitating remote participation of detector experts at the data collection stage and allowing collaborators to remotely monitor experiments; (2) software project management tools; (3) computer system components and supporting software incorporating the use of Quality of Service features generally available in wide area networks; (4) portable systems to hold very large collections of data of the type created in connection with the operation of very large detectors, along with data management tools; (5) visualization and software environments appropriate for physics analysis; (6) software to support data systems distributed over a wide area network; (7) framework, interconnects, and other peripherals which allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual; and/or (8) software development tools for the production of computer software to meet identified problems related to distributed, large scale software development, configuration management, and data analysis. For (8), approaches of interest include distributed portable testing and Computer Aided Software Engineering (CASE), including configuration management tools for a portable, distributed environment; (9) Web tools for remote data selection ("skimming"); and (10) neural nets for optimization of data cuts and pattern recognition.

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PROGRAM OVERVIEW - NUCLEAR PHYSICS

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Nuclear physics research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which, in turn determine the essential physical characteristics of the universe. It is now understood that the most elementary building blocks of matter are particles, called quarks, which interact by the exchange of gluons. Quarks bind together in groups of three to form the nucleons (protons and neutrons) which in turn become the basic building blocks of nuclei. The research forefront in nuclear physics today seeks to understand the properties of nuclei and their limits of stability, how nucleons and nuclei can be understood in terms of their quark substructure, and how nuclear matter behaves under conditions of extreme pressure and temperature. This research is carried out at national accelerator facilities and through university programs.

Nuclear physics research is poised to make important new discoveries, as major new facilities come on line. High intensity electron beams from the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) now allow detailed studies of how quarks and gluons bind together to make protons and neutrons. The Relativistic Heavy Ion Collider (RHIC), now beginning operations at Brookhaven National Laboratory (BNL), will instantaneously form submicroscopic specimens of quark-gluon plasma by colliding gold nuclei, thus allowing a study of the primordial soup of quarks and gluons thought to make up the early universe. A proposed Rare Isotope Accelerator (RIA) facility, is being designed that would provide a way to explore the limits of nuclear existence. By producing and studying highly unstable nuclei that are now formed only in the stars, scientists can better understand stellar evolution and the origin of the elements. Our ability to continue making a scientific impact to the general community relies heavily on the availability of cutting edge technology and advances in detector instrumentation, electronics, software and accelerator design.

The primary mission of the Nuclear Physics program is to develop and support the scientists, techniques, and facilities that are needed for basic nuclear physics research. Attendant upon this core mission are responsibilities to enlarge and diversify the nation's pool of technically trained talent and to facilitate transfer of technology and knowledge to support the nation's economic base. The Nuclear Physics program works in close cooperation with a corresponding program at the National Science Foundation (NSF) and is assisted by the joint DOE/NSF Nuclear Science Advisory Committee in setting scientific priorities.

The SBIR topics which follow describe research and development opportunities in the equipment, techniques, and facilities that are needed to conduct and further nuclear physics research.

10. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program of the Department of Energy (DOE) supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will contribute to fundamental accelerator technology and to applications, which are tailored to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's superconducting Relativistic Heavy Ion Collider with heavy ion energies up to 100 GeV/amu for each beam, superconducting radio frequency (srf) linear accelerators such as the Thomas Jefferson National Accelerator Facility's electron machine, and development of devices and/or methods that would be useful in the generation of intense accelerated beams of radioactive isotopes related to the construction of a Rare Isotope Accelerator (RIA) facility. Relevance of applications to nuclear physics must be explicitly described. **Grant applications are sought only in the following subtopics**:

a. Materials and Components for Radio Frequency Devices—Grant applications are sought for research and development leading to improved or advanced superconducting and room temperature materials or components for radio frequency (rf) devices used in particle accelerators. Areas of interest include: (1) peripheral components such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, and magnetostrictive cavity tuning mechanisms; (2) termination materials for use at 2 to 4 K, compatible with the ultra high vacuum and dust-free environment, and capable of absorbing microwaves

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efficiently from 2 to 90 Ghz; (3) methods to avoid inclusions in the superconducting material and contamination on the surface of the superconductor; and (4) innovative designs for hermetically sealed refrigerators and other cryogenic equipment that simplify procedures and reduce costs associated with reparability and modification; (5) development of simple, low-cost mechanical damping techniques, effective in the 10-300 Hz range at 2 Kelvin, to reduce both construction and operating costs of facilities through smaller systems; and (6) design of optical klystons.

b. Design and Operation of Radio Frequency Beam Acceleration Systems—Grant applications are sought for the design, fabrication, and operation of radio frequency accelerating structures and systems for heavy-ion accelerators. Areas of interest include: (1) superconducting and conventional continuous wave structures for the pre-acceleration of radioactive beams, which can operate in the velocity regime between 0.001 and 0.01 times the velocity of light, for ions with charge-to-mass ratios between 1/30 and 1/240; (2) superconducting rf accelerating structures appropriate for RIA drivers which can operate in segments of the range from approximately 0.1 to 0.8 the velocity of light; (3) the economical fabrication of many-celled rf cavities that still provide moderate damping of all higher-order modes; (4) improved techniques for phase stabilization of low velocity ion acceleration structures; (5) improvements to accelerating gradients and quality factor (Q) in cavities for both continuous wave (cw) and pulsed operation; (6) high duty factor, high power rf systems for radio frequency quadrupoles and linacs; and (7) techniques for coupling rf power into superconducting cavities operating at 2 K.

Grant applications are also sought to develop concepts and designs to improve the stability and performance of high efficiency, high brightness, electron linear accelerator systems. Areas of interest include energy recovery systems that preserve beam quality by thoroughly treating higher order modes and beam break-up phenomena, electron cooling for high-energy ion beams (e.g. RHIC -- Relativistic Heavy Ion Collider -- luminosity upgrade) and electron-ion collisions (e.g. electron collider with RHIC, or eRHIC), and increasing the threshold of multi-bunch, multi-pass beam breakup in energy-recovering electron linear accelerators. Grant applications must address not only beam dynamics but also the engineering issues of such systems by developing system and component level engineering requirements and associated conceptual designs.

Lastly, power requirements could be significantly reduced if the 5 kW, 1500 MHz cw klystrons, currently available for use at nuclear physics accelerator facilities, could be replaced by alternative technology. Grant applications are therefore sought for the design and development of high power solid state devices or other techniques, which would allow for significant reductions in accelerator power usage. The gain should exceed 30 dB and devices should exhibit long life, cost effectiveness, reliability, and high electrical efficiency.

c. Particle Beam Sources and Techniques—Grant applications are sought to develop: (1) particle beam ion sources with improved intensity, emittance, and range of species (areas of interest include high-charge-state sources for heavy ions, sources for negative and light ions, and polarized sources for hydrogen ions and electrons); (2) ion sources for radioactive beams (emphasizing high efficiency, high-charge-state ions, high temperature operation for coupling to high temperature production targets, and element selectivity; e.g., through the use of laser ionization); (3) techniques for secondary radioactive beam collection, charge equilibration, and cooling; (4) methods to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers or special stripping techniques); (5) power supplies to drive these sources; (6) high brightness electron beam sources utilizing continuous wave superconducting rf cavities with integral photocathodes operating at high acceleration gradients; and (7) methods to improve high voltage stand-off and reduce field emission from high voltage electrodes in the presence of work function lowering material (i.e., cesium) in order to enhance the performance of photoemission electron sources.

Grant applications are also sought to develop target materials for radioactive beam production. These targets must be capable of use with beams of protons, neutrons, or heavy ions, with beam power of 10-100 kW, and must be configured for rapid release of isotopes and permit close coupling to an ion source to generate high intensity radioactive beams.

d. Accelerator Control and Diagnostics—Grant applications are sought for: (1) "intelligent" software and hardware to facilitate the improved control and optimization of charged particle accelerators and associated components for nuclear physics research (developments that offer generic solutions to problems in the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning are especially encouraged); (2) advanced beam diagnostics concepts and devices that provide high speed computer-compatible measurement and monitoring of particle beam intensity, position, emittance, polarization, luminosity, momentum profile, time of arrival,

and energy (including such advanced methods as neural networks or expert systems and techniques that are nondestructive to the beams being monitored); (3) beam diagnostic devices that have increased sensitivities through the use of superconducting components, such as filters based on high T_c superconducting technology or Superconducting Quantum Interference Devices; (4) measurements of direct current, charged particle, average beam currents in the range 0.1 to 100 μA with very high precision ($<10^{-4}$); and (5) low current beam diagnostics for radioactive ion beams (for exotic nuclei that will only be available as beams with intensities less than 10^7 nuclei/second -- with such low beam intensities, it is very difficult to use standard beam diagnostic methods).

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*** See Section 7.1

11. NUCLEAR PHYSICS DETECTORS, INSTRUMENTATION AND TECHNIQUES

The Department of Energy (DOE) is interested in supporting projects that may lead to advances in target and detection systems for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art and outside the usual scope of research and development activities at the nuclear physics national accelerator facilities and university programs. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

a. Advances in Particle Detector Technology—Nuclear physics research has a need for devices for detecting and analyzing charged particles, neutrons, photons, and single atoms. These devices include: solid-state devices such as silicon strip and silicon drift detectors; photosensitive devices such as photodiodes, avalanche photodiodes, hybrid photomultiplier devices, single and multi anode photomultiplier tubes, and other novel photon detectors; detectors utilizing photocathodes for Cherenkov and UV light detection, and the development of new types of large area photoemissive materials such as solid, liquid, or gas photocathodes; micro-channel plates; gas-filled detectors such as proportional, drift, streamer, Cherenkov, micro-strip, gas electron multiplier detectors, resistive plate chambers, and straw drift tube chambers; liquid argon and xenon ionization chambers; single-atom detectors using laser techniques and electromagnetic traps; particle polarization detectors; magnetic spectrometer components and systems; electromagnetic and hadronic calorimeters; and position-sensitive segmented germanium detectors. Grant applications are sought to develop advancements in detector technology for all of the above mentioned detectors.

With respect to solid state tracking devices, particularly silicon drift, strip, and pixel detectors, grant applications are sought for: (1) highly arrayed solid state detectors for neutron detection, with integrated electronics to read-out pulse height. (for example, silicon strip or pixel arrays with integrated electronics and coating could be developed so that an alpha-particle is produced when hit with a thermal or cold neutron -- the alpha-particle would recoil into the silicon for measurement resulting in an inexpensive, large acceptance, high rate device); (2) radiation hard silicon detectors; (3) thicker (more than one mm) segmented silicon charged particle and x-ray detectors and associated high density, high resolution electronics; and (4) cost-effective production of n-type and p-type silicon drift chambers with active areas greater than 16 cm^2.

With respect to position sensitive particle tracking devices, grant applications are sought for: (1) position sensitive, high resolution, germanium gamma-ray detectors (determining the exact position, within a few millimeters, and energy of individual interactions of gamma-rays in germanium

detectors, and allowing for the reconstruction of the energy and path of individual gamma-rays using tracking techniques); (2) alternative materials, with the same resolution as germanium for gamma-ray detection, but with significantly higher efficiency and relatively higher temperature operation (in order to overcome the costly and bulky requirement to cool germanium detectors to liquid nitrogen temperatures -- this would allow for new detector applications in nuclear physics, medical imaging, etc.); (3) advances in more conventional tracking detector systems, such as drift chambers, pad chambers, time expansion chambers, and time proportional chambers (areas of interest include improved gases or gas additives -- that resist aging, improve detector resolution, decrease flammability, and offer larger/more uniform drift velocity -- for these chambers, and the development of innovative trackers for RHIC and CEBAF physics such as a fiber optic tracking device).

With respect to particle identification detectors, grant applications are sought for: (1) inexpensive, large-area, high-quality Cherenkov materials; (2) inexpensive, position sensitive large-sized photomultiplier tubes for Cherenkov counters; (3) affordable methods for the large volume production of xenon and krypton gas (which would contribute to the development of transition radiation detectors and would also have many applications in X-ray detectors); and (4) very high resolution particle detectors or bolometers based on semiconductor materials and cryogenic techniques.

Grant applications are also sought for new detector materials for high resolution, light charged particle detectors, capable of measuring energies of alpha particles and protons with less than 5 keV resolution. This would allow spectroscopy experiments using light charged particles to be performed in the same way as gamma spectroscopy, enabling a deeper understanding of nuclear excitations not currently possible with gamma-ray spectroscopy.

b. Scintillators and Associated Materials—Grant applications are sought to develop new materials or advancements for: (1) scintillator materials for high resolution X-ray detectors (CdZeTe, AlSb, etc.); (2) plastic scintillators, fibers, and wavelength shifters; (3) cryogenic liquid scintillation gamma ray detectors (LXe); (3) Cherenkov radiator materials with indices of refraction up to 1.10 or greater with good optical transparency; and (4) stable calorimeter materials in single block lengths (up to 20 radiation lengths) which could be produced in large quantities and at low cost; and composite materials with high radiation resistance.

Grant applications are also sought for new scintillation materials for use in large intermediate-energy photon detector arrays. These materials must exhibit a light output comparable or greater than bismuth germinate, have a fast decay time (in the range from less than one nanosecond to a few tens of nanoseconds) with no slow component, be useful for high rate and/or time of flight applications, have their density and mean nuclear charge be such that the radiation length is less than 2 cm, and be capable of fabrication in large pieces (up to 20 radiation lengths) at reasonable costs.

c. Nuclear Targets—Grant applications are sought for the development of special nuclear targets, which specifically and explicitly address nuclear physics research needs. These special targets include: polarized (with nuclear spins aligned) high-density gas or solid targets; windowless gas targets and supersonic jet targets, for use with very low energy charged particle beams; and liquid, gaseous, and solid targets capable of high power dissipation when high intensity, low emittance charged particle beams are used. There is also interest in new technology for the production of ultra-thin films for targets, strippers, and detector windows.

d. Adhesives—Grant applications are sought to develop special epoxies that could improve the assembly of detectors used in nuclear physics. Of particular interest is an adhesive that can be applied to pieces in a fixture but does not set until an external stimulus is applied (analogous to UV epoxies that cure upon the addition of UV light, except that, in this case, the epoxy is not exposed once the pieces to be glued are assembled in a fixture).

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12. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

The DOE seeks developments in detector instrumentation electronics with improved energy, position and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, and background suppression. Of particular interest is innovative readout electronics for use with the nuclear physics detectors described in Topic 11. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

a. Advances in Digital Electronics—Digital signal processing electronics is needed to replace analog signal processing in nuclear physics applications. Grant applications are sought to develop: (1) digital processors that include the features of current main amplifiers, such as pile-up rejection and ballistic deficit correction; (2) digital pulse processing electronics for solid state detectors, in particular for position sensitive detectors; and (3) fast digital processing electronics in order to determine the position of interaction points (of particle collisions) to an accuracy smaller than the size of the detector segments (note that it will be important to analyze the pulse shape of the preamplifier pulses).

b. Integrated Circuits—Grant applications are sought for special purpose, custom designed integrated circuits and for circuits and systems for rapidly processing data from highly segmented, position-sensitive germanium detectors (pixel sizes of approximately 1 cm^2) and from particle detectors (e.g., gas detectors, scintillation counters, silicon drift chambers, silicon strip detectors, particle calorimeters, and Cherenkov counters) used in nuclear physics experiments. Areas of specific interest include (1) representative circuits such as low noise preamplifiers, amplifiers, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample and hold integrated circuits; and (3) a constant fraction discriminator that has uniform response for low and high energy gamma-rays, as well as a discriminator that can separate neutrons and gamma rays. These circuits should be fast, low-cost, high-density, and configurable in software for thresholds, gains, etc. Compatibility with one of the widely used module interconnection standards (FASTBUS, VMEbus, etc.) would also be highly desirable, as would low power consumption, advanced packaging, adaptability to a large number of multiple channels, and commercial digitizing circuits (ICs, ADCs, FADCs, and TDCs) made available as multi-channel chips (4X, 8X, 16X...).

c. Advanced Devices and Systems—Grant applications are sought for improved or advanced devices and systems used in conjunction with the electronic circuits and systems described in subtopics a and b. Areas of interest include bus systems, data links, event handlers, multiple processors, and fast buffered time and analog digitizers. Generalized software and hardware packages, with improved graphic and visualization capabilities, for the acquisition and analysis of nuclear physics research data are also of interest.

d. Manufacturing Techniques—Grant applications are sought to develop: (1) manufacturing techniques for large, thin, multiple-layer printed circuit boards (PCBs) with plated-through holes with dimensions from 2m x 2m to 5m x 5m and 100-200 micron thick (these PCBs would have use in cathode pad chambers, cathode strip chambers, time projection chamber cathode boards, etc); (2) techniques to add plated-through holes in a reliable, robust way to large rolls of metallized mylar or kapton (this would have applications in detectors such as time expansion chambers or large cathode strip chambers); and (3) miniaturization techniques for connectors and cables with 5 times to 10 times the density of standard interdensity connectors.

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13. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Large scale data storage and processing systems are needed to store, retrieve, and process data from experiments conducted at large facilities, such as Brookhaven National Laboratory's Relativistic Heavy Ion Collider and the Thomas Jefferson National Accelerator Facility. These data, produced at rates of 100 MB/sec or more, result in the annual production of data sets on the order of several hundred Terabytes (TB). Similar data management systems are required to support the needs for non-accelerator nuclear physics experiments. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

a. Data Handling and Distribution—Large scale data storage and access, as well as processing and distribution systems are required for the scientific programs being carried out at Nuclear Physics facilities across the nation. These facilities produce 100s of TB of data per year. Many 10s of TB of data per year are distributed to many institutions around the U.S. and other countries for analysis by the scientific collaborators. Grant applications are sought for (1) hardware and software techniques to improve the effectiveness and reduce costs of handling such large data volumes, and (2) hardware and software techniques to improve the effectiveness of the computational and data grids (see reference 2) for these uses.

Projections of the cost of data storage media show that magnetic disk media will soon be competitive with magnetic tape for storing large volumes of data. However, the infrastructure costs of operating a petabyte disk storage system could be prohibitive with current technology that keeps all disk drives powered and spinning. A characteristic of nuclear physics datasets is that most of the data is accessed infrequently. Therefore, grant applications are sought for new techniques leading to petabyte-scale magnetic disk systems that have low cost and low power usage that scale linearly with the amount of data accessed rather than total storage capacity.

b. Maintenance of Scientific Databases—The legacy of nuclear physics research is the data produced. Large projects like RHIC, Gammasphere, or the Jefferson Laboratory produce unique data that may never be re-measured. Experience tells us that only a small portion of the data is ever analyzed and published. Typical large research projects

focus on the experiment and data taking but not database preservation. Therefore, grant applications are sought to develop permanent archiving and Internet dissemination procedures for nuclear physics experiments.

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PROGRAM AREA OVERVIEW - NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

http://www.ne.doe.gov

Continued use of nuclear power is an important part of the Department's strategy to provide for the Nation's energy security, as well as to be responsible stewards of the environment. Nuclear energy research currently provides over 20 percent of the U.S. electricity generation and will continue to provide a significant portion of U.S. electrical energy production for many years to come. Also, nuclear power in the U.S. makes a significant contribution to lowering the emission of gases associated with global climate change and air pollution.

The Office of Nuclear Energy, Science and Technology (NE) enables the Department of Energy to provide the technical leadership necessary to address critical domestic and international nuclear issues by administering research and development and technical assistance in the following general areas: (1) the Nuclear Energy Research Initiative (NERI) Program addresses key issues affecting the future of nuclear energy in order to preserve U.S. nuclear science and technology leadership, (2) the Radioisotope Power Systems Program develops new state-of-the-art radioisotope power systems to support the NASA space missions and terrestrial applications for other agencies, (3) the Nuclear Energy Plant Optimization (NEPO) Program conducts research to assure the continued safe and reliable operations of over 100 of the Nation's nuclear power plants, (4) the University Reactor Fuel and Educational Assistance Program is designed to help retain the U.S. nuclear engineering capability for conducting nuclear research, addressing pressing nuclear environmental challenges, and preserving the nuclear energy option, and (5) the Isotope Production Program produces and sells hundreds of stable and radioactive isotopes that are widely used by domestic and international customers for medicine , industry and research applications.

14. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power is an important component of the Nation's energy supply system, providing over 20 percent of the U.S. electricity without emitting harmful air pollutants, including those that cause adverse global climate change. New methods and products are needed to address key issues affecting the future of nuclear energy and to preserve U.S. nuclear science and technology leadership. This topic addresses several of these key issues: improvements in nuclear reactor technology; computer software, simulation, and modeling; and advanced thermoelectric devices and materials for improved radioisotope power systems. **Grant**

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applications are sought only in the following subtopics:

a. New Technology for Improved Nuclear Energy Reactors—Advances are needed for key system and component technologies that would ultimately be used in the design, construction, or operation of existing and advanced nuclear energy power plants. Grant applications are sought to: (1) optimize nuclear reactor plant and component system control, including the accurate measurement of key reactor and plant parameters, by developing advances in instrumentation, controls, and sensors; (2) assess plant and equipment performance and monitor aging, by developing advanced diagnostic techniques for in-service and non-destructive examination; and (3) improve corrosion resistance for light-water-reactor coolant system components, as well as for secondary side stream and feed water equipment, by exploring advances in materials and chemistry control. (See references 3-6, 8-12, 15, 17). Grant applications that address complete nuclear reactor or plant design concepts are not of interest and will be declined.

b. Advanced Computer Software, Simulation, and Modeling Applications—Advanced computational techniques are needed for the design, development, testing, and evaluation of existing and advanced nuclear power reactor systems. Grant applications are sought for new software for simulation and modeling efforts (including parallel processing techniques) to support one or more of the following needs: (1) design, development, and experimentation of new and existing nuclear reactors and major reactor components, including advanced fission fuel core thermal-hydraulic design features; (2) advanced remote, automatic, in-place systems for characterizing nuclear waste and harmful by-product elements generated from nuclear reactors and power plants; (3) assessment, measurement, control, and management of nuclear reactor and plant performance, integrity, and operations. (See references 3-6, 8-12, 15, 17). Grant applications that address complete nuclear reactor or plant design concepts are not of interest and will be declined.

c. Thermoelectric Devices and Materials for Improved Performance of Radioisotope Power Systems—Radioisotope Thermoelectric Generators (RTG) have been the sole electrical power systems employed for NASA deep space exploration missions such as Voyager 1 and 2, Galileo, Ulysses, and more recently Cassini. These power systems provide units of power equal to nominally 100 or 300 watts electrical, and multiples thereof. The RTG provide very long life reliability, but their conversion efficiencies are low, typically 6.5 to 7.5 percent when the silicon-germanium unicouple is used as the thermoelectric conversion device. Due to changes in mission plans and philosophy, future NASA requirements will include higher conversion-efficiency units with power levels from 50 to about 200 watts, and much smaller power RTGs with power levels from 40 to 500 milliwatts. In anticipation of these future needs, grant applications are sought to develop:
(1) an improved segmented unicouple (See references 2, 13-14, 16) which has a minimum target efficiency of 14 percent and is operational in a vacuum environment at temperatures of 300°C and 1000°C for the cold and hot junctions, respectively (the Phase I effort should use unicouple geometry (reference 13) to guide the conceptual design for a segmented unicouple, select materials, make preliminary predictions of conversion efficiency; and explore -- and if possible -- demonstrate intersegment bonding) and/or

(2) a series and/or parallel milliwatt thermopile (see references 1 and 7) with a design based on the peripheral geometry of the current series connected thermopile (reference 13) and producing the same voltage/current output (the Phase I effort should initiate plans for manufacturing and demonstration, while Phase 2 would include completing the development and demonstration of the manufacturing process, as well as the manufacture of test hardware and a demonstration of performance).

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* See section 7.1

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PROGRAM AREA OVERVIEW
DEFENSE NUCLEAR NONPROLIFERATION

http://www.nn.doe.gov

The worldwide proliferation of Weapons of Mass Destruction (WMD) and their missile delivery systems is one of the most serious dangers confronting the United States. This danger is continuing, with far-reaching consequences for international security and stability. Based on the highly specialized scientific, technical, analytical, and operational capabilities of the Department and its National Laboratories, the Department of Energy (DOE), through its Office of Defense Nuclear Nonproliferation (NN), is uniquely suited to provide leadership in national and international efforts to reduce the danger to U.S. national security posed by WMD. Within NN, the Office of Nonproliferation Research and Engineering conducts applied research, development, testing, and evaluation -- and leverages the work of others -- to produce technologies that lead to prototype demonstrations and resultant detection systems, thereby strengthening the U.S. response to current and projected threats to national security and world peace posed by the proliferation of nuclear, chemical, and biological weapons, and the diversion of special nuclear material. Specific objectives include developing technologies for: (1) remote detection of the early stages of a proliferant's nuclear weapons program; (2) location, identification, and characterization of nuclear explosions underground, underwater, in the atmosphere, and in space, to enhance the U.S. nuclear explosion monitoring capability; (3) nuclear materials protection, control and accounting; monitoring nuclear arms control agreements; and detecting the movement of nuclear materials; (4) and detecting the proliferation or use of chemical and biological agents, and minimizing their consequences. Developed technologies are transitioned to other government users or are directly commercialized.

Small businesses that submit grant applications under the following topics are encouraged to collaborate (formally or informally) with DOE national laboratories. Where necessary, collaborations may be arranged after awards are made. The objective is to help the small businesses get a better understanding of DOE's requirements and to help integrate each company with the potential DOE-related users of the technology.

15. SENSOR TECHNOLOGY FOR DETECTING THE PROLIFERATION OF WEAPONS OF MASS DESTRUCTION

The United States Department of Energy (DOE) is responsible for the development of systems for detecting the proliferation of weapons of mass destruction, including nuclear, chemical, and biological weapons. In both cooperative and non-cooperative environments, it is necessary to have the capability to detect the production, storage, transportation, and testing of such weapons. DOE's overall objective is to provide this capability by putting state-of-the-art technologies and tools in the hands of the treaty verification, law enforcement, and other relevant communities. **Grant applications are sought only in the following subtopics:**

a. Advanced Research in Support of Nuclear Explosion Monitoring—The DOE is responsible for research and development necessary to provide the U.S. Government with the capabilities needed to monitor and/or verify compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). To monitor compliance with the CTBT, the treaty calls for an International Monitoring System consisting of a network of seismic, radionuclide, hydroacoustic and infrasound data collection stations. Grant applications are sought to develop, within the context of one or more of these technologies, algorithms, hardware, and software for improved event detection, location, and identification/screening at thresholds and confidence levels that meet U.S. requirements in a cost-effective manner. For example, a procedure to determine the size of an infrasound event would be of special interest in support of discrimination studies. Grant applications must demonstrate how proposed approaches would complement ongoing or completed work (see http://www.ctbt.rnd.doe.gov/coordination) while improving capability. Program priorities focus primarily on the advancement of seismic technologies.

Event detection includes the development of innovative sensor designs (e.g., microseismometers), signal-processing techniques, or instrumentation that significantly improve signal-to-noise ratios, or improve detection where low signal-to-noise ratios exist. Also of interest are new approaches to instrumentation where benefits to sensitivity, reliability, discrimination, or function can be achieved. Sensors must be

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compact, inexpensive, easily manufactured, reliable under adverse conditions, robust, simple to maintain, and have low power requirements.

Event location and identification/screening of nuclear explosions includes the ability to discriminate these explosions from non-relevant events such as earthquakes and non-nuclear man-made events. Accuracy depends on regional studies that provide high-quality ground truth information (geology, meteorological conditions, data on man-made events, etc.) and/or seismic wave propagation information that allow calibration of individual stations for travel times and/or amplitudes. High quality ground-truth data is of particular interest. Any proposed modeling effort must be strongly tied to regional data or must demonstrate applicability to a particular geophysically distinct region.

b. Biological Agent Detection—Early detection of a biological attack, whether by direct detection of airborne biological agents or rapid detection of those who have been exposed (pre-symptomatic), is essential to minimize the impact of such attacks. Grant applications are sought for improvements in techniques that specifically capture biological pathogens and allow for signal transduction. Of particular interest are approaches that would ultimately lead to improved biological detection through higher sensitivity, specificity, or shelf-live of reagents, or via decreased dependence on reagent use or sample preparation. Proposed approaches need not be antigen-based, but may include nucleic acid recognition or other possible mechanisms. Samples could be either gaseous or aqueous base. Approaches of interest include, but are not limited to, structurally based ligand design, molecularly imprinted polymers, combinatorial receptor design or phage display. Preference will be given to approaches that have broad application to classes of pathogens and detect biological targets relevant to the Chemical and Biological Nonproliferation Program (CBNP) mission (see www.nn.doe.gov/cbnp) rather than those that focus loosely on surrogate compounds.

c. Fast Neutron Detection—As part of the U.S. effort to deter smuggling of special nuclear material (SNM), the DOE is developing technologies to detect illicit shipments of SNM coming into U.S. ports of entry, such as in cargo containers. To improve this capability, grant applications are sought for the development of detector systems with the ability to directly detect fast neutrons and determine their energy and direction. Directly detecting fast neutrons, versus detecting thermal neutrons, is important because information such as energy and direction is lost after neutron scattering has occurred. The ultimate goal is to develop the capability to image neutron sources similar to what can be done with gamma-ray sources. Approaches of interest include developing new detector materials and/or devising innovative detection schemes with currently available technology. Approaches that provide real time results are preferred and the system must be able to work in the presence of high levels of gamma-rays compared to the number of neutrons available for detection. Generally, there are 1,000 to 10,000 times more gamma-rays than neutrons hitting a particular detector.

d. Spectral Analysis of Chemical Composition—Grant applications are sought to develop technology, including theories and algorithms, for the chemical analysis of samples by using their emission or absorption spectra, when the number of the possible chemicals from which the sample could be composed exceeds the number of spectral channels used to measure the sample. The analysis should include the use of physical constraints (e.g., that only non-negative concentrations are physically possible) and the possible use of *a priori* information on the probability of the presence of and likely concentrations for the various chemicals. Proposed approaches must determine measures of the overall level of confidence for the presence of key chemicals, determine confidence intervals for their concentrations, and identify what has not been determined by the spectral measurement.

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16. SUPPORT TECHNOLOGIES FOR SENSORS USED IN NATIONAL SECURITY APPLICATIONS

The DOE Office of Defense Nuclear Nonproliferation (NN) sponsors the development of many types of sensors to help detect the proliferation of weapons of mass destruction. This topic is focused on the development of techniques and components to improve the capability or drive down the cost of development of such sensors. The first three subtopics are primarily focused on support systems for the development of micro-chemical sensors where there is significant demand to decrease size, weight, and power requirements. The last subtopic is focused on improving remote sensing capabilities by "fusing" the data from existing types of sensors to significantly improve the ability to detect or classify signatures of interest. **Grant applications are sought only in the following subtopics:**

a. Microfluidics for Micro-Analytical Instruments—The DOE sponsors the development of micro-chemical sensors to improve the ability to perform real time in-field chemical analysis. The goal is to achieve low power consumption, light weight and small size while maintaining sensitivity and selectivity. Systems under development employ techniques such as micro-fabricated gas chromatography, capillary electrophoresis, surface acoustic wave and chemi-resisters sensors, only to name a few. There is a need for practical, off-the-shelf sample handling systems for use in the development of these micro-analytical devices. Therefore, grant applications are sought for the development of micro-fluidic sample handling systems (valves, pumps, filters, interconnects, and other sample handling items) for use in micro-fabricated chemical sensors. The goal is to take existing or new concepts in microfluidic components and develop MEMS (micro electromechanical systems) based systems for commercial production to meet the needs of real-world applications. Shortcomings in existing commercial components include excessive packaging volume, excessive fluid dead space in interconnects, use of pneumatic actuators that require relatively large pressure vessels with limited field lifetimes, high voltage and/or power requirements, inability to maintain a seal in a powered-off state, and inability to handle liquids. Proposed techniques must show compatibility with a wide range of fluids (especially acids, bases, and organics), low "off" state/zero-power leakage, and proven reliability. Typical systems apply low (less than10 pounds per square inch gage) pressure service for gas and liquid with sample volumes in the micro to nanoliter range. Liquid pumps must be self-priming. Proposed approaches must provide a practical method to interconnect these components into complete microfluidic systems, as well as a clear path toward scalable manufacturability at low cost. While no single technology can meet all conceivable user needs, it is hoped that standardized approaches might lead to a level of interchangeability as seen in the electronics industry. Ultimately, a "field-configurable microfluidics array" might include pre-installed pumps, valves, and universal external ports with an array of fluid channels that can be reconfigured for multiple applications. As a result, the need for non-recurrent engineering efforts and the cost of each particular system should be significantly reduced.

b. Ultra Violet/Visible Micro-Laser Excitation Sources —Grant applications are sought for the development of compact, robust, wall-plug efficient, blue and ultraviolet (488 nanometers to 220 nanometers wavelength), micro-laser sources for use in optical based micro-chemical and biological sensor systems. Requirements include continuous wave (CW) output greater than 10 to 20 milliWatt, round output beams with high beam quality (M^2 less than or equal to 1.2), and amplitude stability less than or equal to 5 percent root-mean-square. Due to the broadband absorption spectra of the compounds of interest, linewidth, wavelength accuracy and stability specifications can be relaxed (± several nanometers at the output wavelength). Either direct semiconductor laser based systems or efficient diode pumped frequency converters are desired. Small form factors and low prime power are also required. Modular device architectures with fiber coupled outputs are preferred. Grant applications are also sought for subcomponent technologies for micro-laser excitation sources. As an example, diode-pumped CW ultraviolet frequency converters with wavelengths less than 320 nanometers require the

fabrication and development of efficient nonlinear UV transparent waveguides that can be quasi-phase matched, and also require thermally-bonded UV transparent waveguides that incorporate birefringence phase matching. Also of interest are approaches based on nonlinear waveguide resonators for enhanced conversion efficiencies at low drive powers. Teaming is encouraged to produce system level devices.

c. Modeling and Design Tools for Heterogeneous Photonic Integrated Circuits— Photonic integrated circuits provide an unprecedented route to economical, robust sensor systems. They are the optical analog to electronic integrated circuits (ICs). Due to the rapid explosion of photonics in the telecommunications industry, several commercial photonic foundries are now available that can fabricate custom devices. However, universal design software that can handle both active and passive waveguides, as well as nonlinear and linear waveguide structures, is lacking. This is also true for nanostructured photonic bandgap materials. Commercial availability of this type of software would dramatically impact photonic based sensor technology and significantly reduce development time and cost. Therefore, grant applications are sought for the development of computational simulation software that can model two dimensional beam propagation effects in complex photonic devices involving heterogeneous optical materials, with device feature sizes that encompass a range of length scales from sub-wavelength to thousands of wavelengths. Grant applications must include physics modules capable of handling optical nonlinearities, active gain media, random index variation and multi-wave interactions. Specific phenomena of interest include waveguide harmonic generation, quasi-phase matched interactions with uniform and chirped gratings, integrated optical parametric oscillation, four-wave mixing, pump depletion, gain saturation effects, waveguide nonlinear absorption and power limiting effects, and localization in photonic bandgap materials. Proposed approaches must produce a comprehensive multiple-length-scale, photonics design tool driven by a user friendly graphical design interface (GUI), suitable for operation on a personal computer or workstation. For these platforms, it is desirable to minimize run time and memory requirements through the use of adaptive multi-resolution algorithms where possible.

d. Integrated Data Exploitation for Remote Sensing—The Office of Nonproliferation Research and Engineering supports the development of sensor in areas such as Synthetic Aperture Radar (SAR), multi-spectral and hyper-spectral imaging, imaging and non-imaging LIDAR (light detection and ranging) and radio frequency (RF) detection for treaty monitoring and nonproliferation. Most projects focus on developing advanced sensors as well as on the associated signal processing needed to derive useful information from the data stream produced by the individual sensor under development. Synergistic processing and exploitation of data from different types of sensors is typically beyond the scope of individual sensor research projects. Therefore, grant applications are sought to improve remote sensing data processing and data exploitation when multiple data sources of different modality {e.g., spectral information, terrain features (topography, CAD & engineering models of structures, object databases), meteorological (air temperature, humidity, lightening strike statistics, surface winds, etc.), or other data} are available. Examples include: (1) the use of topographic data from Interferometric-SAR (IFSAR) to apply appropriate Bi-directional Reflectance Distribution Function (BRDF) coefficients for spectral data, thus enhancing spectral analysis; (2) the use of terrain categorization from spectral data to aid foliage penetration modeling of SAR data; (3) CAD models of buildings or IFSAR topography and thermal imagery to aid thermal energy dissipation analysis; and (4) the use of RF beacon propagation information to correct for ionospheric phase distortion of SAR data. Application areas include urban/natural environments and human/environmental features on the ground, on the water, or in the air. Grant applications may address any form of remote sensing, including those mentioned above as well as electro-optical, radio frequency, and others. It is not necessary to address all features in all environments or for all sensor types. Simple, but effective, concepts are welcome. However, the DOE is most interested in formalisms and architectures that are eventually expandable to cover the broadest range of problem types, environments, sensor types, and data types.

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PROGRAM AREA OVERVIEW
ENVIRONMENTAL MANAGEMENT

http://www.em.doe.gov

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

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The responsibilities of DOE's Office of EM include (1) the remediation of radioactive and toxic wastes to their original background levels at hundreds of DOE sites and the deactivation and decommissioning (D&D) of thousands of radiation-contaminated facilities and (2) the characterization, treatment, shipping, and disposal of transuranic and mixed waste. Long term monitoring will be required for both site remediation and facilities. It will be needed to track the migration, if any, of residual contaminants, assure that the agreed-upon contaminant levels are maintained, and monitor the formation and/or destruction of chemical, biological, and radiological products and by-products. Improvements in long term monitoring technologies will assist DOE in its responsibilities for long term stewardship, which includes all activities required to protect human health and the environment at DOE sites after the selected cleanup strategies are complete. Regarding the characterization, treatment, shipping, and disposal of transuranic and mixed waste, EM needs new or improved solutions to handle wastes that will be generated in the future, primarily from environmental restoration and D&D activities.

The following two topics solicit grant applications for long-term monitoring technologies and stewardship activities needed at either remediation sites or facilities and for technologies needed for characterization, treatment, shipping, and disposal of transuranic or mixed waste. Background information on the DOE needs can be found on the World Wide Web (http://ost.em.doe.gov/ifd/stcg/needs.htm).

17. TECHNOLOGIES FOR TRANSURANIC AND MIXED WASTE MANAGEMENT

The Department of Energy's Office of Environmental Management (EM) is responsible for the characterization, treatment, shipping, and disposal of thousands of cubic meters of transuranic waste (i.e., radioactive waste contaminated with uranium 233 or transuranic elements having half lives of over 20 years, in concentrations greater than 1 ten-millionth of a curie per gram of waste) and mixed waste (i.e., mixtures of radionuclides and RCRA hazardous materials). EM manages thirty-six sites storing about 165,000 cubic meters of mixed low level and transuranic waste. In addition, the Department projects that 45,000 cubic meters of transuranic waste and 170,000 cubic meters of mixed low level waste will be generated over the next ten years, primarily from environmental restoration and deactivation and decommissioning activities. (Note: mixed low level waste is a combination of low level radioactive waste and RCRA hazardous waste.) About sixty percent of the total inventory is categorized as transuranic waste and is packaged in a variety of containers, from 55-gallon drums to fairly large cargo containers. Most of the transuranic waste is destined for disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. For most of the inventory's mixed low-level waste, treatments are prescribed in Consent Orders between the sites and their host states.

The subtopics below identify four problem areas driven by site-specific needs. Additional information about these problems can be found on individual Websites through links located at:

http://wastenot.inel.gov/mwfa;
http://ost.em.doe.gov/tms;
http://mwfadata.inel.gov/doclistneed.asp?id=mw07;
http://mwfadata.inel.gov/doclistneed.asp?id=mw01;
http://mwfadata.inel.gov/doclistneed.asp?id=mw05;
and http://mwfadata.inel.gov/doclistneed.asp?id=mw06.

Grant applications are sought only in the following subtopics:

a. Alternatives to Incineration for the Decontamination of Organics in Transuranic and Mixed Waste—High activity, plutonium-238 contaminated transuranic waste is stored within the Department of Energy complex. These wastes may not be shippable to the Waste Isolation Pilot Plant due to the excessive generation of hydrogen gas resulting from radiolysis of organic constituents. Furthermore, there are no standard processes for the decontamination (separation and extraction) of plutonium. Incineration processes, oxidation processes, and reduction processes, which are used for the destruction of organics, have limited application to these waste streams. Grant applications are sought for technology to decontaminate the sub-micron size plutonium-238 in the waste stream. Proposed concepts must meet the following requirements: use of chemicals that require little special handling; containment of the plutonium; ability to achieve a volume reduction; minimal waste generated by the concept itself; and existence of a suitable disposal path for any waste stream generated.

b. Characterization of Radionuclides, RCRA Material, and Organics in Remotely Handled Waste—Various regulatory drivers and management needs, as well as

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stringent Waste Isolation Pilot Plant acceptance criteria for transuranic waste, require the detailed characterization of radioactive and hazardous components within transuranic, mixed transuranic, and mixed low level waste. (Note: mixed transuranic waste is a combination of transuranic waste and RCRA hazardous waste.) Currrently, there is no standard non-destructive method for identifying and quantifying the radionuclide, organics, and Resource Conservation and Recovery Act (RCRA) material content in waste drums that are remotely handled (i.e., using robotic systems). Grant applications are sought for the non-destructive assay (identification and quantification) of radionuclide and RCRA material content in these waste drums.

A related problem is the identification and quantification of organics in remotely handled small waste samples. The current method for is to extract a sample, transfer the sample to an on site laboratory, and use destructive analysis methods. Grant applications are also sought for nondestructive concepts that will allow for the sampling and analysis of small remotely handled organic waste samples, and for destructive concepts that will reduce the waste generated by the current sampling and analysis methods by 50 percent.

For radionuclide material, proposed systems must be able to perform in a high radiation environment (greater than 200 milli-rem per hour contact; Plutonium-239 fissile gram equivalents; total alpha activity; transuranic activity; individual radioisotopes and quantities; and thermal power). For RCRA materials and for organics, proposed systems must be non-intrusive, semi-intrusive and nondestructive, or intrusive but operated at-line or online; generate data in real time (less than 15 minutes); be readily employed in a glove box environment; be compatible with specific waste material types (debris, sludges, liquids); meet all Waste Isolation Pilot Plant Quality Assurance Program Plan requirements; and meet all Environmental Protection Agency SW-846 requirements.

c. Hydrogen Getter Materials—To minimize the potential for the loss of hazardous material when transuranic waste is transported in TRUPACT-II containers, the Nuclear Regulatory Commission (NRC) has imposed a limit on the concentration of flammable (hydrogen) gas -- 5 percent by volume of hydrogen, the explosive limit of hydrogen in air. The limit applies to the innermost layer of confinement within a drum or standard waste box. In order to prevent the explosive limit from being reached or approached, hydrogen gas getters (solid materials that remove hydrogen from the gas phase) have been investigated for removing hydrogen from the air inside the TRUPACT-II container. Sol-gel metal hydride, ceramic metal hydride, and polymer microencapsulated materials are currently being evaluated for this application. Grant applications are sought for new materials (not including those mentioned above) that will allow for the effective removal of hydrogen gas in these waste containers. Proposed materials must satisfy the following parameters: irreversible collection of hydrogen under the wide conditions that may occur during transport (20 to 160 degrees Fahrenheit, and 0 to 50 psig); ability to operate in the presence of other gases present in transuranic waste (e.g., halogenated and other volatile organic compounds); no oxygen requirement; no water produced as a reaction product; operation as a passive system; and ability to maintain hydrogen concentration under 5 percent for a period of 60 days in the presence of hydrogen gas generation rates of 1.2 E10-5 moles per second. Also, it should be noted that although repackaging or treatment of wastes does not require NRC approval, the application of hydrogen getter materials in the TRUPACT-II must be approved by the NRC prior to use.

d. Emissions Control and Monitoring for Both Non-Thermal and Thermal Treatment Facilities—The emission of hazardous gases (at low, medium, and high concentration levels) from both non-thermal and thermal processes continues to be an important issue for major stakeholders and regulators. In the future, both stakeholder expectations and proposed regulations are expected to become more stringent. However, there is no current standard practice for mitigating the generation of dioxins and furans in the off-gas streams of non-thermal and thermal processes, and there are no off-the-shelf instruments for measuring dioxins, furans, and multiple metals at the off-gas discharge point. Grant applications are sought for concepts to mitigate the generation of dioxins and furans in the off-gas streams of both non-thermal and thermal systems, and for concepts to continuously measure dioxins, furans, and multiple metals at the off-gas discharge point. Proposed concepts must satisfy the following requirements: relative accuracy in accordance with 40 CFR 60 Appendix F; the Methods Detection Limit (the minimum concentration of a substance that can be measured and reported, with 99 percent confidence that the analyte concentration is greater than zero, and with the detection limit determined from an analysis of a sample in a given matrix type containing the analyte); *in situ* measurement capability; ruggedness; and portability.

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18. MONITORING OF DOE SITES, FACILITIES, AND PERSONNEL

The Office of Environmental Management (EM) is responsible for cleaning up radioactive and toxic waste at contaminated sites and facilities throughout the DOE nuclear weapons complex, preventing further environmental contamination, and instituting responsible environmental management. At the end of FY 1997, 60 of the 113 contaminated sites had been cleaned up. By 2006, the Environmental Management program intends to complete cleanup at most of the 53 remaining sites. The cost-effective monitoring of hazardous materials and worker conditions would provide the accurate data needed to protect health and the environment, as well as facilitate the clean-up process. Contaminants present at DOE sites and in facilities include hazardous organic compounds, metals, and radionuclides covering a wide spectrum of individual substances, matrices, and complex mixtures. Monitoring devices and/or systems should be able to withstand representative environmental conditions and be able to operate without an external power supply for extended periods of time. **Grant applications are sought only in the following subtopics:**

a. Remote Monitoring of Soils, Geologic Formations, and Groundwater at Remediated Sites—Monitoring of environmental sites will be required for a 30 to 100 year period after the initial characterization and remediation actions are completed. The intent of such long-term surveillance and monitoring is to verify that remediation efforts have met site goals and that no unexpected contaminant releases or migrations have occurred. Typically, these long-term monitoring commitments are finalized with stakeholders and regulators upon the acceptance of the site closure plan. For some sites, the cost of long-term monitoring over decades can equal or exceed the original remediation cost. A scientific foundation of knowledge is needed to support the development of new and innovative sensor systems that can significantly decrease the cost, as well as improve the performance, of this long-term environmental surveillance and monitoring requirement. Grant applications are sought to develop remote sensors and systems (both *in situ* and *ex situ*) for the long-term, remote monitoring of contaminants in soils, geologic formations, and groundwater at remediated sites. Contaminants of interest are radionuclides, hazardous materials (i.e., RCRA metals and organics), and mixtures of radionuclides and hazardous materials ("mixed waste").

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b. Remote Monitoring Within DOE Facilities—Many facilities throughout the DOE Complex will reside in a safe storage or surveillance and maintenance (S&M) mode until such time that funding resources are available to perform decontamination and demolition. Typically, contaminant levels within these facilities have been, or will be, reduced to levels that minimize the likelihood of a release to the environment. However, long-term monitoring systems will still be required to ensure against, or provide rapid response to, a release condition. Grant applications are sought for remote techniques for the long-term monitoring and detecting of airborne contaminants (e.g., for plutonium isotopes, beryllium, tritides, etc) and of facility conditions that could impact contaminant release (e.g., structural integrity, water infiltration, air movement, etc.).

c. Data Management—In order to utilize the information provided by a variety of monitoring systems, improved data characterization and management systems will be needed to facilitate long-term S&M and final disposition planning. Grant applications are sought for data management and facility modeling systems for the storage, retrieval, tracking, and analysis of facility characterization data, as well as visual and spatial images of the facility and associated equipment and waste. Of particular interest is the identification and mapping of localized "hot spots." Proposed systems must be capable of receiving input data from photographs, videos, laser range finders, gamma cameras, as well as from facility drawings, site databases, waste inventories, and computer aided design packages. Systems must be controllable from remote locations and be capable of sending and accessing data via phone, computer, or cable lines. Lastly, grant applications must address the ease and automation of system calibration and maintenance.

d. Worker Heat Stress and Monitoring—Workers performing characterization and deactivation/decommissioning (D&D) actions require protection from exposure to radioactive and hazardous materials, which may exist at the DOE site. Cumbersome protective gear, hot summer temperatures, indoor work in nonventilated areas, and physically demanding work hinder a worker's ability to remain cool. Excessive heat stress impairs judgement, reduces muscle motor response, and creates undesirable conditions for performing tasks. To relieve heat stress, workers require frequent breaks during the remediation effort. Worker health and safety is an important part of the D&D and remediation efforts and innovations are needed to reduce health and safety risks and to improve the level of protection, comfort, and worker productivity. Grant applications are sought for improvements in personal protective equipment and clothing to alleviate heat stress while maintaining protection from radiological and chemical exposures; proposed concepts must be lighter and more comfortable than current worker's gear and clothing. Grant applications are also sought for improved real-time sensors for physiological monitoring of the worker (e.g. blood pressure, skin temperature, motion, and breathing rate), in order to assess the medical basis for heat stress and other physiological conditions that would indicate that the worker is suffering undue stress.

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http://www.clu-in.org

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U.S. DOE Office of Science and Technology
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* See Section 7.1

PROGRAM AREA OVERVIEW
BIOLOGICAL AND ENVIRONMENTAL RESEARCH

http://www.er.doe.gov/production/ober/ober_top.html/

The Biological and Environmental Research (BER) program invests in peer-reviewed research at national laboratories, universities, and private institutions in order to develop the knowledge and resources needed to identify, understand, and mitigate the long-term health and environmental consequences of energy production, development, and use. The major objectives of the BER program are to contribute to a healthy citizenry, contribute to the cleanup of the environment, and understand global climate change.

To contribute to a healthy citizenry, BER supports fundamental research and technology development needed for mapping the fine structure of the human genome, which will provide the valuable information needed to identify disease genes and develop broad therapeutic and diagnostic strategies. BER projects also develop advanced imaging and other medical technologies, including highly sensitive radiotracer detectors, radiopharmaceuticals and boron compounds with affinities for tumors. In support of the

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nation's biomedical, pharmaceutical, and environmental activities, BER projects make use of unique facilities at the Department of Energy national laboratories to determine biological structure and how it relates to function at the molecular and cellular level.

To contribute to cleanup of the environment, BER supports fundamental research necessary for the development of advanced remediation tools for cleaning up DOE's contaminated sites, particularly in support of DOE's Office of Environmental Management.

To understand global environmental change, BER projects acquire the data and develop the understanding necessary to predict global and regional climate changes, which may be induced by increasing atmospheric concentrations of greenhouse gases.

19. ENVIRONMENTAL MONITORING TECHNOLOGIES FOR SOILS, SUBSURFACE SEDIMENTS, AND GROUNDWATER

The characterization and monitoring of soils, subsurface sediments and groundwater are important elements of Department of Energy (DOE) research efforts. Objectives include determining the fate and transport of wastes generated from past weapons production activities and from current energy production activities, evaluating the risks of energy-related contaminants to human health and ecosystems, and assessing and controlling processes to remediate contaminants.

Grant applications must detail why and how proposed *in situ* field technologies will substantially improve the state-of-the-art and must include bench tests to demonstrate the technology. Projected dates for likely operational field deployment must be clearly stated. New or advanced field technologies that (1) operate in subsurface environments with mixed/multiple contaminants and (2) can be deployed in 2-3 years will receive selection priority. Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements with government laboratories or universities. Claims of commercial potential for proposed technologies must be supported by information such as endorsements from relevant industrial sectors, market analysis, or identification of commercial spin-offs. Grant applications that propose incremental improvements or enhancements to existing technologies are not of interest and will be declined, as will enhancements to predictive models. **Grant applications are sought only in the following subtopics:**

a. Real-Time, *In Situ* Measurements in Soils, Subsurface Sediments, or Groundwater—There is a need for sensitive, accurate, and real-time monitoring of geochemical and hydrogeologic processes and their interactions with biological organisms in contaminated soil, subsurface sediments, or groundwater environments (hereafter referred to as the subsurface). The use of highly sensitive monitoring devices in the subsurface (*in situ*) would allow for low-cost field deployment in remote locations and an enhanced ability to monitor processes at finer levels of resolution. Grant applications are sought to develops sensors and systems to: (1) detect hydrogeologic and biogeochemical processes that control the transport, dispersion, or transformation of contaminants (particularly metals and radionuclides) in the subsurface; (2) determine characteristics such as concentration, movement, or valence state of contaminants (particularly metals and radionuclides) in the subsurface; and/or (3) measure mass-transfer processes and rates within and among individual pores in the subsurface. Grant applications are also sought for integrated sensing and controller/signal processing systems for autonomous or unattended applications of the above measurement needs. Innovative integration of components (such as micro-machined pumps, valves, and micro-sensors) into a complete sensor package with field applications in the subsurface will be considered responsive to this subtopic.

Approaches of interest could include fiber optic, solid-state, chemical, silicon micro-machined sensors, or biosensors (devices employing biological molecules or systems in the sensing elements) that can be used in the field. Biosensing systems may incorporate, but are not limited to, whole cell biosensors (chemoluminescent or bioluminescent systems), enzyme or immunology-linked detection systems, membrane lipids, or DNA/RNA probe technology with amplification and hybridization. As substantial progress has been made in fiber optics and chemical sensing technology in the last decade, grant applications that propose minor adaptations of readily available materials/hardware, and/or can not demonstrate substantial improvements over the current state-of-the-art, are not of interest and will be declined.

b. Rapid Molecular Analysis of Microorganisms—DOE is currently funding research to investigate the use of naturally occurring communities (multiple species) of

microorganisms for the *in situ* bioremediation of contaminants (particularly metals and radionuclides) in the subsurface. Metals of interest include chromium, lead and mercury; radionuclides of interest include cesium, plutonium, strontium, technetium, and uranium. It is essential to understand what microorganisms exist, the extent to which particular microorganisms tend to associate with one another within a microbial community, and whether any have a tendency to be associated with the contaminants. Grant applications are sought for the *in situ* analysis of individual microbes and microbial communities in the subsurface. Proposed approaches should: (1) characterize consortia and communities, or (2) determine the spatial arrangement, physiological status, or taxonomy of microorganisms. Although Bacteria and Archaea are of greatest interest, methods for the analysis of Eukarya will also be considered.

Possible technologies for assessing microbial community structure include: (1) DNA microarrays and DNA "chip" technologies for rapid detection of genes associated with key microbial species in natural microbial communities (such as metal-reducing bacteria or sulfate-reducing bacteria), or genes associated with metal transformation or metal resistance: and (2) flow cytometric technologies for rapid analysis and sorting of community DNA in naturally occurring microbial populations. Other *in situ* approaches for rapid analyses of microbial communities or their DNA would also be considered, provided they could be applied to the subsurface.

b. Phytoremediation Monitoring—Phytoremediation involves the use of living plants to extract and remove metals, radionuclides, and organic contaminants from soils, subsurface sediments, or groundwater. Innovative methods are needed to monitor the performance or effectiveness of phytoremediation processes, particularly at the field scale. Performance or effectiveness monitoring is needed to determine whether cleanup levels have been met. Grant applications are sought to develop technology for monitoring the following parameters of plants used in phytoremediation: (1) the concentration and partitioning of contaminants in plant roots (sorbed or bound and internal), shoots, stems, and leaves; (2) root depth, distribution, density, and diameter: (3) mortality, health, and vigor of plants (stress indicator); (4) photosynthetic rates; (5) leaf area and evapotranspiration, and/or (6) plant tolerance or sensitivity to contaminants of interest to DOE.

Potential monitoring technologies could include: (1) spectral reflectance and thermal infrared measurement techniques, (2) laser-induced fluorescence spectroscopy and laser-induced fluorescence imaging, (3) laser-induced breakdown spectroscopy, (4) x-ray fluorescence, (5) ground-penetrating radar, (6) chlorophyll fluorescence measurements, and (7) molecular methods for monitoring soil and rhizosphere microbiology. Both remote monitoring and *in situ* monitoring approaches are of interest. Proposed technologies should significantly improve the speed, efficiency, and cost of current monitoring methods. While initial proof of principle experiments may focus on one single contaminant, the technology ultimately must be able to operate under mixed contaminant conditions such as those commonly found at DOE sites.

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20. ATMOSPHERIC MEASUREMENT TECHNOLOGY

World-wide energy production is modifying the chemical composition of the atmosphere and is linked with environmental degradation and human health problems. The radiative transfer properties of the atmosphere may be changing as well. Various technological developments are needed for high accuracy and/or long term monitoring of these changes to support a strategy of sustainable and pollution-free energy development for the future.

Grant applications must propose Phase I bench tests of critical technologies. Critical technologies are those components, materials, equipment, or processes that significantly limit current capabilities in one of the specific subtopics that follow. For example, grant applications proposing only computer modeling without physical testing will be considered non-responsive. Grant applications should also describe the purpose and benefits of any proposed teaming arrangements with government laboratories or universities in the technical approach or work plan. Applications submitted to any of the subtopics should support claims of commercial potential for proposed technologies, (e.g., endorsements from relevant industrial sectors, market analysis, or identification of potential spin-offs). **Grant applications are sought only in the following subtopics:**

a. Trace Gas Measurements Aboard Aircraft—Studies of the sources and fates of nitrogen compounds and oxidants in the troposphere require the development of innovative instrumentation. Grant applications are sought to develop instruments to measure concentrations of ammonia (NH_3) and nitric acid vapor (HNO_3) in the lower few kilometers of the atmosphere. The instruments must be sufficiently small, lightweight, and low in power consumption for use aboard medium or small aircraft (e.g. CONVAIR, Gulf Stream 1, Twin Otter, Dash 7, and smaller) that are flown at these altitudes over urban and regional distances (i.e., several hundred miles). Proposed systems must be capable of providing real-time measurements (i.e., the time for both sampling and response should be less than one minute) and be sufficiently sensitive to detect concentrations as low as 0.01-0.05 parts per billion. Grant applications must include detailed descriptions of the instrumentation (including how it will connect to the atmosphere, for the purpose of sampling, without interference from intake losses or other confounding factors) and demonstrate how the proposed technique will result in improved aircraft measurement capabilities. Promising approaches for measuring nitric acid include chemical ionization mass spectroscopy (CIMS) and tunable diode laser (TDL) infrared spectroscopy. In addition, other potential candidate technologies and related sampling problems have been identified in the literature. For the measurement of ammonia, photofragmentation-laser-induced flourescence (PD-LIF) has shown the potential for 5 ppt detection with 5-minute integration times.

b. Radiometric Instrumentation—Measurements of shortwave solar radiation (0.3 to 3.0 micrometers) and thermal radiation (3 to 100 micrometers) provide necessary information about the chemical and physical state of the atmosphere and earth's surface. Current broadband solar instruments include pyranometers, pyreheliometers, and shadowband radiometers while solar spectral instruments include scanning filter photometers, shadowband radiometers, and spectroradiometers. Thermal instruments include broadband infrared radiometers (pyrgeometers), interferometers, and grating spectrometers. Grant applications are solicited to develop radiometric instrumentation or radiometer components that: (1) improve current performance of broadband shortwave radiometers (e.g., it is desirable to achieve consistent one percent accuracy by eliminating the need for domed covers and/or other sources of uncertainty such as angle of incidence, temperature, pressure, and humidity effects on detectors, optical components, and windows); (2) significantly reduce drift, poor angular response, dome and window contamination (e.g., dust and water) errors, nighttime offsets, thermal imbalance errors, leveling sensitivity or other sources of error; (3) significantly reduce the cost of ancillary equipment such as solar seekers and trackers without degrading performance; or (4) improve the current performance of pyrgeometers to measure hemispherical irradiance in the infrared (3 to 50 micrometers) region (e.g., it is desirable to avoid contamination by solar radiation and to develop improved methods of calibration). Applicants may focus on critical components and ancillary equipment

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for radiometers including detectors, radiation standards and calibration methods, filter systems and monochromators, and solar tracker/seekers. Applications that make only incremental improvements to existing radiometric devices will be declined.

c. Automatic Measurement and Characterization of Cloud Particles—There is a need to develop miniaturized instrumentation for automatic measurement and characterization of cloud particles. Grant applications are sought to develop instruments for measuring the size of cloud particles from about 5 to 1,000 μm and provide information on particle shape and the degree of particle riming. Of particular interest are instruments that can also measure the scattering phase function and provide some measure of polarization properties. Data from the instrument must be recorded digitally (i.e., not on a VCR) and particle sizing must be accomplished without the need for extensive manual analysis of the data. Instruments must be capable of operating continuously in moderate icing conditions and should weigh less than 8 kg. The instrument must also be suitable for deployment on tethered balloons/kite platforms and small, unpiloted aerospace vehicles (UAVs).

d. Instrumentation for Characterizing Organic Substances in Aerosol Particles—Important insights into atmospheric pollution can be gained by understanding the characteristics and temporal changes of organic substances in ambient atmospheric aerosol particles with diameters less than about 2.5 micrometers. Grant applications are sought to develop instrumentation for real-time measurements that will: (1) provide accurate estimates of both mass and speciation of organic matter as a function of particle size; (2) detect the changing degree of oxygenation of the organics in aerosols, in order to evaluate the photochemical evolution of the organic aerosol; or (3) identify isotopic and molecular-level tracers of primary and secondary organic carbon, in order to help understand the origins of the fine particulate matter. The instrumentation and associated systems must account for such factors as polarity and water solubility, and must be capable of extended operation in an outdoor, field environment. Methods are needed that will provide accurate measurements of the organic aerosols with minimal artifacts (for example, semivolatile organics are known to absorb and desorb from filter media used to collect the organic aerosol samples) for both field and aircraft operations and for both organic carbon and black carbon. Examples of past approaches include determining $^{14}C/^{12}C$ isotopic ratios as a means of estimating fossil/biogenic hydrocarbon contributions to the aerosols, optical measurements of the "blackness" of the sample as a means of determining black carbon (soot) contributions, and thermal evolution techniques.

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21. BIOLOGICAL CARBON SEQUESTRATION RESEARCH AND TECHNOLOGY

The burning of fossil fuels adds carbon to the atmosphere, principally in the form of carbon dioxide, and the potential environmental impacts have made carbon management an international concern. There is increasing national and international interest in finding natural mechanisms to mitigate the current atmospheric rise in CO_2 levels, and the Department of Energy (DOE) is focusing increasing attention on novel approaches for carbon sequestration.

The DOE is developing a comprehensive carbon management program to develop innovative scientific and technological solutions to sequester excess CO_2, which could slow the current rate of increase of greenhouse gases in the atmosphere. A DOE working paper on carbon sequestration

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science and technology (see reference 2) describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems, including a discussion of advanced biological processes and chemical approaches. This topic is concerned with the biological conversion of atmospheric CO_2 into relatively stable organic or inorganic forms, thus fixing the gas either as usable commercial products or as inert environmentally neutral forms. To attain this goal, research is needed to identify and quantify CO_2 sequestration mechanisms and rates that will lead to the long term fixation or sequestration of large quantities of carbon (i.e., 10,000 to 100,000 tonnes or more of carbon per year) when the derived approaches are applied to natural and managed systems.

Terrestrial ecosystems and agriculture or forest production systems are the focus of this Topic.

Grant applications must provide for a systematic evaluation of proposed biological mechanisms and carbon sequestration systems. Estimates of the amount of CO_2 fixed also must be provided, and any assumptions concerning quantities and conditions for carbon fixation and sequestration must be clearly defined. Feasibility tests (analytical, bench, or field) performed in Phase I must demonstrate that scaling up the proposed approach can theoretically result in a significant reduction in atmospheric CO_2 concentration, or can contribute to a significant reduction in the rate of atmospheric CO_2 increase. It is expected that preliminary data will be delivered on prospective rates and quantities of enhanced carbon fixation/sequestration by conclusion of Phase I, and that more comprehensive and peer-reviewed data sets will be delivered by the end of Phase II.

Grant applications proposing only computer modeling without improvements in physical mechanisms or field approaches will not be considered. Also, the generation of value-added by-products (e.g., food, fiber, energy) as a result of sequestration research is highly desirable.

Applicants should consider collaborating with the DOE Center for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE), led by a consortium based at Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). The co-directors are Gary Jacobs (ORNL/e-mail: jacobsgk@ornl.gov) and Blaine Metting (PNNL/e-mail: fb_metting@pnl.gov). Other collaborators include scientists from Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, the Rodale Institute in Pennsylvania, and the Joanneum Research Institute in Austria. Coordination with carbon sequestration research at the National Energy Technology Laboratory (NETL) is also encouraged.

Grant applications are sought in the following subtopics:

a. Microbial Fixation and Transformation of Carbon—Various terrestrial and oceanic microbial populations fix CO_2 and transform the resulting photosynthetic products into residual organic compounds. Biogeochemical pathways have been identified in microorganisms that: fix carbon dioxide and produce methane that can be captured as an energy source; fix carbon monoxide and produce hydrogen (also an energy source); and fix either carbon monoxide or carbon dioxide to produce various molecules with potential biotechnological or industrial uses. Grant applications are sought to:

(1) isolate and identify naturally occurring micro-organisms capable of fixing large quantities of CO_2/CO and concurrently producing methane or other high-value product, or

(2) develop technology to modify existing micro-organisms, either by conventional strain selection techniques or by genetic engineering, to enhance CO_2 fixation and the generation of energy (e.g., hydrogen) and/or other products (e.g., food, fiber).

For either items (1) or (2) to be considered as part of a managed CO_2 sequestration system, grant applications also must demonstrate that the yield of CO_2-fixed products would be significantly enhanced. For potential deployment in terrestrial systems, a microbiologically engineered approach should show a capability to increase carbon sequestration by at least 1 tonne per hectare per year. Phase I must demonstrate feasibility and efficacy of proposed sequestration mechanisms, with the large-scale system and commercial applications designed and tested in Phase II.

b. Plant and Soil Sequestration of Carbon—Terrestrial, vascular plants effectively capture CO_2 from the atmosphere and produce organic compounds which sustain productivity of the Earth's ecosystems. Some of the fixed carbon is sequestered in soils or wood products of terrestrial ecosystems, and some accumulates in soils and sediments. Woody species, for example, sequester carbon as lignocellulose, which is a stored product for the lifetime of the tree. Also, for example, above- and below-ground biomass carbon contributes to soil organic matter, which may

store carbon for long periods of time. Grant applications are sought to identify and quantify the biological pathways and mechanisms leading to increased quantities of carbon sequestration by soil and biotic components of terrestrial ecosystems. Areas of particular interest include the identification or development of one or more of the following:

(1) terrestrial organisms, and/or metabolic pathways and enzymatic modifications, that enhance the removal of CO_2 from the atmosphere;

(2) genetic selections and genetic engineering approaches that result in deposition of a greater fraction of photosynthetic product into forms that more effectively sequester carbon;

(3) methods for altering functional interactions of ecosystems, and/or for modifying the ecological relationships among terrestrial organisms, that could potentially shift the carbon balance of ecosystems in the direction of greater carbon sequestration and increased storage of "natural" long-lived organic compounds;

(4) methods for accelerating transformations of labile vegetable matter into soil organic matter fractions resistant to oxidation back to CO_2, and

(5) innovative technologies and methods to increase carbon content of soils through enhanced production and retention of residual forms of organic matter.

Proposed research should provide information about rates and quantities of carbon sequestration by terrestrial biotic and soil systems. The resulting technologies and approaches should exhibit a capability to increase carbon sequestration by at least 1 tonne per hectare per year. Phase I must demonstrate feasibility and efficacy of proposed sequestration mechanisms, with the large-scale system and commercial applications designed and tested in Phase II.

c. Biohydrogen Production Linked to Carbon Sequestration—Hydrogen is considered to be an environmentally desirable fuel because its combustion product (water) is non-polluting and because it can be produced in renewable energy systems. Some photosynthetic microorganisms are capable of consuming CO_2 from the atmosphere and simultaneously generating hydrogen. Therefore, grant applications are sought for microbial combinations or systems for which the simultaneous production of hydrogen and sequestration of carbon are optimized. Research questions to be investigated include:

(1) Is the physiology/metabolism of hydrogen producing *and* carbon sequestering organisms compatible, and can their functions produce different end-products when cultured together?

(2) What forms of microbial modification (e.g., genetics and culture) might conceivably enhance the simultaneous production of hydrogen and the formation of non-labile (sequestered) carbon compounds?

(3) How might linked microbial processes be optimized to produce both hydrogen and useful carbon products?

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22. CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

Eighty-five percent of our nation's energy results from the burning of fossil fuels from vast reservoirs of coal, oil, and natural gas. These processes add carbon to the atmosphere, principally in the form of carbon dioxide (CO_2). It is important to understand the fate of this excess CO_2 in the global carbon cycle in order to assess the terrestrial ecosystem response, the sensitivity of climate, and the potential for sequestration in natural carbon sinks of lands and oceans. Therefore, improved measurement approaches are needed to quantify carbon changes in components of the global carbon cycle, particularly the terrestrial biosphere, in order to improve understanding and assess the potential for future carbon sequestration.

A DOE working paper on carbon sequestration science and technology describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems (see Reference 2). This document calls for substantially improved technology for measuring carbon transformation of the atmosphere and biosphere. The document also describes advanced sensor technology and measurement approaches that are needed for detecting changes of carbon quantities of terrestrial (including biotic, microbial, and soil components) and oceanic systems, and for evaluating relationships between these carbon cycle components and the atmosphere.

Grant applications submitted to this topic should demonstrate performance characteristics of proposed measurement systems, and show a capability for deployment at field scales ranging from experimental plot size (meters to hectares of land -- with comparable dimensions for marine systems) to nominal dimensions of ecosystems (hectares to square kilometers). Research to develop miniaturized sensors to determine atmospheric CO_2 concentration is also encouraged. In addition, Phase I projects must perform feasibility and/or field tests of proposed measurement systems to assure high degree of reliability and robustness. Combinations of remote and *in situ* approaches will be considered, although priority will be given to ideas/approaches for verifying biosphere carbon changes and for estimating carbon sequestration.

Lastly, applicants should consider collaborating with one of the two DOE centers for carbon sequestration research, which include both laboratory and university participation. One Center is investigating carbon sequestration by terrestrial ecosystems, and the other focuses on carbon sequestration by oceans. Applicants with an interest in such collaboration should contact one of the directors listed below:

- The DOE Center for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE) is led by a consortium based at Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). The co-directors are Gary Jacobs (ORNL/e-mail: jacobsgk @ornl.gov) and Blaine Metting (PNNL/e-mail: fb_metting@pnl.gov). Other collaborators include scientists from Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, the Rodale Institute in Pennsylvania, and the Joanneum Research Institute in Austria.

- The DOE Center for Research on Ocean Carbon Sequestration (DOCS) is led by Lawrence Livermore National Laboratory (LLNL) and Lawrence Berkeley National Laboratory (LBNL). The co-directors are Ken Caldeira (LLNL/e-mail: kenc@llnl.gov) and Jim Bishop (LBNL/e-mail: jkbishop@lbl.gov). Other collaborates include scientists from MIT, Rutgers, Scripps, Moss Landing Marine Labs, and the Pacific International Center for High Technology Research.

Grant applications are sought only in the following subtopics:

a. Sensors and Techniques for Measuring Terrestrial Carbon Sinks and Sources—Measurement technology is required to quantify carbon sequestration by natural vegetation and ecosystems (i.e., carbon sinks) as well as CO_2 emissions to the atmosphere from natural or industrial sources. Grant applications are sought to develop remote, ground-based sensors and unique measurement techniques (and associated system technology, if appropriate) to detect and quantify annual net carbon changes of terrestrial vegetation for large areas, or to measure and verify the magnitude of CO_2 emissions from various sources. For the measurement of CO_2 sinks, the sensor systems or new technology must be applicable for forests, grasslands, shrub lands, agricultural lands, and/or wetlands, and have the capability of producing spatially resolved aggregate estimates of terrestrial carbon changes to an accuracy of 10

to 25 g/m^2/yr (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty. For measuring emissions, the apparatus must be located at a point remote from the actual site of CO_2 release and provide accuracy estimates for CO_2 concentrations of approximately 0.5 ppm or less.

Mechanical sensors must be durable in the full range of normal environmental conditions and exposures, including exposure to dust, rain, snow, heat, extreme cold, and fog. Operation in unattended, remote locations for weeks at a time, without degradation of the measurement, is also required; however, daily telecommunication with the system for monitoring performance and detecting potential operational problems would be desirable.

Proposed approaches, including both mechanical sensors and non-mechanical technology should consist of new, innovative methodologies that are significant advances over conventional scientific approaches used to measure CO_2, carbon, and related compounds. Specifically, the measurement systems should be different from, or substantially augment, existing methods for eddy flux (covariance), routine monitoring of atmospheric CO_2 concentrations, or estimating carbon quantities of land and/or ocean constituents of the carbon cycle. Grant applications proposing *in situ* or in-stream measurement of flue gas emissions will be declined, as will applications that offer only incremental or marginal improvements over existing measurement systems.

b. Novel Measurements of Organic Substances and Carbon Isotopes in Terrestrial and Atmospheric Media—Improved measurement technology is needed to better characterize processes involving carbon transformations of soil, vegetation, and associated ecosystem components and exchanges with the atmosphere. This includes both carbon content and isotopic measurements of organic matter in soils and other solid substrates, as well as the carbon content of biological tissues in various components (e.g., phytomass, detritus) of terrestrial ecosystems.

Grant applications are sought for measurements of carbon content in the atmosphere, vegetation, soil, and associated environmental media. For measurements involving the carbon content of biota and soil, grant applications must demonstrate that these measurements can be used to predict changes in carbon quantities and/or fluxes involving major components of ecosystems, with an accuracy on the order of 10 grams per square meter or less. Quantification of spatially resolved aggregate estimates of terrestrial carbon changes should have an accuracy of 10 to 25 g/m^2/yr (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty.

For measurements of atmospheric CO2, development of lightweight (approximately 100 gram) sensors capable of measuring fluctuations of CO2 in air of the order of plus or minus 1 ppm in a background of 370 ppm is solicited. The devices must be suitable for launch on ballonsondes or similar such platforms, and therefore must be insensitive to large changes in ambient temperature and pressure. They must be able to operate on low power (e.g., 9v battery), and have a response time of less than 30 seconds.

Grant applications are also sought for unique, rapid, and cost-effective methods for measuring the natural carbon isotopic composition of plant, soil, and atmospheric materials. The idea is to use isotope technology to identify sources and sinks of carbon materials, and to use carbon isotopes to distinguish relative carbon exchanges between terrestrial or aquatic media and the atmosphere. New isotope approaches and technology should demonstrate a quantitative capability for both estimating and distinguishing carbon flux among atmosphere, biosphere, and soil components of natural and manipulated carbon cycles.

Proposed new measurements of terrestrial biota and soil must be accomplished by *in situ* and/or non-invasive means and/or remote sensing of organic carbon forms across a range of temporal scales (from seconds to days) and spatial scales (from millimeters to kilometers), depending on the system properties being observed. Instruments must be portable and deployable in remote locations, and must not adversely impact the site of deployment. The term "remote sensing" means that the observation method is physically separated from the object of interest. Research that develops unique surface-based observations and uses them for calibration/interpretation of other remotely derived data is of interest; however, except for potential application of CO2 sensor via ballonsonde, other methods of remote sensing data acquisition by airborne or satellite platforms will not be considered.

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23. MEDICAL SCIENCES

The Department of Energy (DOE) Medical Sciences program covers a broad range of energy-related technologies including nuclear medicine, boron neutron capture therapy, and biomedical engineering. DOE is interested in innovative research involving medical technologies to facilitate and advance the current state of diagnosis and treatment of human disorders.

In biomedical engineering, principles of physics, chemistry, and engineering are employed to advance fundamental concepts dealing with human health, create knowledge from the molecular to the organ systems level, and develop innovative biologics, materials, processes, implants, devices, and informatics systems for the prevention, diagnosis, and treatment of disease and for improving human health. The DOE Biomedical Engineering program seeks to capitalize on the unique bioengineering capabilities at the DOE's national laboratories to develop new technologies that will have a significant impact on human health.

With respect to nuclear medicine and boron neutron capture therapy (BNCT), current areas of research include the development of: (1) radiopharmaceuticals as radiotracers to study *in vivo* chemistry, metabolism, cell communication, and gene expression in normal and disease states, and as therapeutic agents; (2) new radionuclide imaging systems; and (3) technological advances for boron neutron capture therapy including new boron-labeled, tumor-seeking compounds and mini-accelerator-based neutron beams. **Grant applications are sought only in the following subtopics:**

a. Micro/Nano Technologies for the Rapid Assessment of Medical Drugs—Grant applications are sought that exploit recent advances in micro and nano technology and molecular biology to develop miniaturized medical instruments that can be used in both clinical and remote settings to rapidly and reproducibly measure/monitor drugs of medical interest. Grant applications that include collaborations with one or more DOE's national laboratories are highly desired. Applications must demonstrate that the proposed technology is an improvement over current clinical procedures and that the technology will have an impact on human health.

b. Radiopharmaceutical Development for Radiotracer Diagnosis and Targeted Molecular Therapy—Grant applications are sought to develop: (1) radiolabeled compounds that could have applications as radiotracers for

radionuclide imaging technologies such as positron emission tomography and single photon emission computed tomography; (2) improved and simplified production of radiolabeled compounds through the use of mini-accelerator technology or automated radiochemical analysis/synthesis techniques; and (3) radiopharmaceuticals for targeted molecular therapy. Of particular interest are radiochemical, synthetic, and combinatorial molecular engineering approaches. All efforts should ultimately result in a product for nuclear medicine use.

c. Advanced Imaging Technologies—Grant applications are sought for new, sensitive, high resolution instrumentation for radionuclide imaging. The instrumentation should advance the application of radiotracer methodologies for imaging molecular biological functions including cell communication and gene expression *in vivo*. Areas of interest include the development of: (1) new detector materials and detector arrays for both positron emission and single photon tomography; (2) software for rapid image data processing and image reconstruction; and (3) methods of integrating *in vitro* and *in vivo* instrumentation technologies for real time molecular imaging of biological function and for new drug development and utilization.

d. Boron Neutron Capture Therapy (BCNT)—Grant applications are sought for: (1) development of boron-labeled compounds that have an affinity for tumor cells *in vivo* and are capable of delivering lethal cellular radiation after neutron irradiation, and (2) the design and development of novel and inexpensive mini-accelerators to create epithermal neutron beams suitable for BNCT.

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24. GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

The Department of Energy (DOE) supports research to acquire a fundamental understanding of biological and environmental processes. This research includes the characterization of genomes and gene products from humans and other organisms; structural biology research using beamlines at synchrotron sources and other facilities; as well as studies in computational structural biology, computational genomics, and biological information systems. Knowledge gained in this research is used to exploit genomic information, determine the structure of biological macromolecules, integrate advances in computational and mathematical sciences into biology, understand protein folding mechanisms, and clarify the relationships between genes, gene product structures, and biological function. Such knowledge should enable the public and private sector to: (1) markedly improve human health care and promote worker and public safety; (2) promote application of DNA-based biotechnology to environmental applications, like bioremediation; (3) facilitate the isolation, characterization, and treatment of factors involved in human diseases and disorders; and (4) promote cleaner industrial processes using biotechnology. Close interactions with one of the DOE laboratories or projects can be beneficial in the development of a grant application. **Grant applications are sought only in the following subtopics:**

a. Genomic Analysis Technologies—Several genomic analysis resources and technologies, initially developed under basic research grants, have now matured to the point where commercialization has become a distinct possibility. Grant applications are sought to further develop one or more of the following technologies, leading to kits or services that could be offered for sale: (1) clone libraries derived from single copy vectors, such as BACs (bacterial artificial chromosomes) and fosmids; (2) probe reagents supporting fractionation of the genome into chromosomal components; (3) economical kits of STS primer pairs, to support analyses of "gene families" across populations.

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b. DNA Mapping Methods for Chromosome Analysis—The annotation of genomes and/or chromosomes with sequence based markers is useful for clarifying the chromosomal constituents of a species, intrachromosomal structure analysis, and quality control of the algorithmic assembly processes of DNA sequencing. DNA optical mapping and DNA fibre FISH (fluorescence *in situ* hybridization) are technologies that support this annotation at kilobase resolutions, while retaining long range DNA continuity information. Grant applications are sought to further develop these technologies, leading to mapping services for them and their eventual transfer to interested customers. In addition, applications for novel technologies (in addition to DNA optical mapping and DNA fibre FISH) that would achieve the same objectives will also be considered. Constituents of interest include biochemical, instrumentation, and computational analyses.

c. Gene Products and Interactions— Production methods for making dense arrays of oligomers and nucleic acids are well established for analytic and diagnostic readouts. However, a need remains for the development of comparable protein arraying technologies. These technologies can potentially be used in massively parallel tests of bio-activity, monitoring metabolic status, biochemical processes, and/or exposure to external materials. To address this need, grant applications are sought to develop: (1) microarrays of uncharacterized gene products (for functional analysis); (2) microarrays of gene products to assess interactions with other biomolecules (including nucleic acids); or (3) microarrays of gene products to assess physiological states. Grant applications should include a discussion of how the output signals or data will be processed, so that these microarray technologies, if successful, could potentially be incorporated into automated systems.

d. Informatics Support of Functional Analysis—The draft human genome will mature into a highly finished sequence over the next two years. An increasing number of genomes of model organisms and microbes are also being displayed as DNA sequence of chromosomes. Computational support for the functional analysis of these immense information resources is of increasing importance. Grant applications are sought to further develop software and computation tools for the processing and analyzing of genome scale information resources and large sub-families thereof. Grant applications must demonstrate that the tools will lead to services that will aid users who are non-specialists in computer sciences and that the services will be complementary to, rather than directly competitive with, public and private sector services already well established.

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   a. End Sequencing
      (1) University of Washington Department of Molecular Biotechnology
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   b. History - Sequence Tag Connectors Production on Human BACs
      http://www.ornl.gov/meetings/bacpac/index.html
   c. National Center for Biotechnology Information
      http://www.ncbi.nlm.nih.gov
   d. Production
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      http://informa.bio.caltech.edu/idx_www_tree.html
      (2) Roswell Park Cancer Institute BACPAC Resource Center
      http://bacpac.med.buffalo.edu/
   e. Protein Data Bank of the Research Collaboratory for Structural Bioinformatics
      http://www.pdb.bnl.gov/
   f. U.S. DOE Office of Biological and Environmental Research
      http://www.er.doe.gov/production/ober/ober_top.html

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   http://www-hgc.lbl.gov/instr/weier.html

3. Human Genome Project Information
   http://www.ornl.gov/hgmis/

4. Nucleic Acid Database of Rutgers University
   http://ndbserver.rutgers.edu/NDB/ndb.html

5. Optical Mapping
   http://www.nyu.edu/projects/genomics/omm.html

PROGRAM AREA OVERVIEW
ADVANCED SCIENTIFIC COMPUTING RESEARCH

http://www.sc.doe.gov/production/octr/index.html

The Office of Advanced Scientific Computing Research (ASCR) supports research in computational technology and laboratory technology research, subprograms that underlie a variety of Department of Energy missions.

ASCR's primary mission, carried out by the Mathematical, Information, and Computational Sciences subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex phenomena important to the Department of Energy. To accomplish this mission the program fosters and supports fundamental research in advanced scientific computing – applied mathematics, computer science, and networking – and operates supercomputer, networking, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently run these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research provides the techniques to link the data producers; e.g.,

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supercomputers and large experimental facilities with scientists who need access to the data. The two topics that follow support this scientific computing mission.

The Laboratory Technology Research subprogram funds high-risk, multidisciplinary research partnerships between the DOE's Office of Science multi-program national laboratories and private industry. Projects supported explore applications of basic research advances in the investigation of problems, over a full range of scientific disciplines, whose solutions have promising commercial potential.

25. HIGH PERFORMANCE NETWORKS

The Department of Energy (DOE) supports a wide range of research activities in mathematics, information, and computational sciences to support distributed high-end computing, remote instrumentation and data storage, and scientific collaboration in DOE. Many emerging energy research problems require computational resources not currently available in a single DOE facility. These problems generate an enormous amount of data that must be remotely analyzed and visualized by scientists in geographically distributed scientific facilities. The distributed nature of these problems calls for secure high-performance network infrastructures to support collaboration and resource sharing on a national and international scale. The current Internet, built with commodity components and optimized for low-speed, best-effort applications, lacks the capability and functionality to deliver the level of performance and security required by DOE scientific applications and collaborations. Therefore, research is needed to enhance the performance and capabilities of network services, transport protocols, network control and management, and other features that contribute to the overall security, survivability, and scalability of contemporary networks. Grant applications must clearly state how the proposed research will be beneficial to the long-term mission of DOE and at the same time make significant contributions to the general subject areas. **Grant applications are sought only in the following subtopics:**

a. Agile Optical Network Technologies—New technology is needed to harness and extend the unprecedented bandwidth capability offered by Dense Wave Division Multiplexing (DWDM) to the DOE high-performance computing and high-end scientific applications. Grant applications are sought to develop agile optical network technologies leading to the development and deployment of highly reconfigurable optical network components, optical routing and switching technologies, scalable link layer framing protocols, and optical interconnects for supercomputers and cluster computing. Areas of interest include: (1) scalable non-SONET (Synchronous Optical Networks) framing mechanism for Internet Protocol (IP) over DWDM at OC-192 (Optical Carrier level 192 -- concatenated at 2.5 Gbps) rates and above; (2) optical interconnects for the interconnection of supercomputers, cluster computing hardware, and storage devices; (3) Multi Protocol Label Switching (MPLS) over dynamically reconfigurable lambda-switched networks; (4) performance characterization of legacy protocols (Point-to-Point Protocol (PPP), High Data Link Control (HDLC), and Ethernet frames) operating over terabits/sec optical links. Grant applications must address optical network issues of specific interest to the DOE computing environment

b. Network Instrumentation and Control—Grant applications are sought to develop technology to support high speed networks (OC-12 to OC-192 speeds) and network-aware applications using innovative, secure, and scalable techniques and tools to predict the behavior and performance of transport and network layer protocols, routing and switching algorithms, and middleware, leading to robust estimates of the end-to-end performance of operational networks. Areas of interest include: (1) tools for passive and active monitoring, transport protocol (e.g., Transmission Control Protocol (TCP), User Datagram Protocol (UDP)) auto-tuning, and backbone network traffic analysis; (2) measurement, monitoring (active and passive), and dynamic optimization of end-to-end of network performance and reliability; and (3) predictive and intelligent techniques for analyzing data collected by network monitoring equipment and SNMP (Simple Network Management Protocol) derived data. The techniques and tools must target areas of interest to DOE application development.

c. Network Security—Grant applications are sought to develop tools and techniques for: (1) secure and fair means for enabling application and user access and control of network resources; (2) smart network management (i.e., highly capable network management agents, tools and stations) that adapt to a dynamic network infrastructure; and (3) innovative techniques for intrusion detection using Artificial Intelligence (neural networks, fuzzy logic, etc.) and

advanced statistical techniques. The tools and techniques must be applicable throughout the high speed network. Grant applications must address appropriate public key infrastructure (PKI) research that supports these efforts and that is interoperable and consistent with industry-driven and government PKI.

d. Quality of Service—Quality of Service (QoS) issues focus on technologies, protocols, and architectural frameworks that address relevant issues of end-to-end service at the application level in distributed environment and in grid computing. QoS grant applications are sought to develop: (1) technology for the parameterization and integration of QoS mechanisms implemented for distributed high-end applications; (2) dynamic QoS mechanisms to allow for the graceful degradation of applications; (3) innovative techniques and tools for the testing, measurement, and evaluation of QoS mechanisms, and/or (4) bandwidth broker architectures for multi-domains.

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   http://www.es.net

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4. IETF Draft: Multi-Protocol Lambda Switching: Combining MPLS Traffic Engineering Control with Optical Crossconnects
   http://search.ietf.org/internet-drafts/draft-awduche-mpls-te-optical-02.txt

5. IETF RFC2823: PPP Over Simple Data Link (SDL) Using SONET/SDH with ATM-Like Framing
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   http://www.ccic.gov

7. Networked Computing for the 21st Century.
   Washington, DC: National Science and Technology Council, 1998. (Available from the National Coordinating Office for Computing, Information and Communications, 4201 Wilson Boulevard, Suite 690, Arlington, VA 22230. Telephone: 703-306-4722. Fax: 703-306-4721)

8. Next Generation Internet (NGI)
   http://ngi.gov

9. QBONE (Cooperative Advanced Quality of Service Testbed)
   http://qbone.internet2.edu/

10. U.S. Department of Energy, Office of Science
    http://www.science.doe.gov

26. HIGH PERFORMANCE SYSTEMS SOFTWARE

The Department of Energy (DOE) sponsors a wide range of research activities in mathematics, information, and computational sciences to support high-end computing that is required to solve leading edge scientific problems critical to DOE's missions. The solution of these problems requires hundreds of gigaflops to multiple teraflops of computing power. Currently available computer architectures are based on clusters of symmetric multiprocessor nodes built with commodity components and optimized for mid-range commercial or scientific applications. In order to achieve acceptable performance on large clusters where 100s or 1000s of processors must effectively work on a single application, significant specialized software is needed. Therefore, to enhance the performance and capabilities of these clusters, improvements are needed in operating systems, system management and queue management software, and performance monitoring and improvement tools. Grant applications must clearly state how the proposed research will benefit DOE's long-term mission and at the same time make significant contributions to the general subject areas. In addition, grant applications must demonstrate that the proposed research is scalable to 1000s of processors. Priority will be given to technical approaches that build upon open source software and which support interoperability across all operating systems important to the high end community, including both proprietary and open source systems. **Grant applications are sought only in the following subtopics:**

a. System Management Software—Cluster management encompasses a wide range of tasks such as configuring new nodes, monitoring the state of the system and rebooting when

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necessary, and upgrading and installing new software. System vendors have supplied management tools for their products, but clusters built by end users are typically administered with *ad hoc* tools that are particular for a given site. Research in large clusters has generally not focused on systems management approaches or techniques. Grant applications are sought for innovative ways to manage large clusters of commercial computers. Areas of interest include power and fault management, software configuration control across nodes, and hardware and software status monitoring.

b. Queue Management Software—Resource management software is used to assure that appropriate resources (computational, network, storage), meeting user and application requirements, are available to applications when needed in the face of complex scheduling and allocation constraints. The best match of resources to applications can vary dramatically depending on the emphasis required (e.g., emphasis on high system utilization vs. emphasis on immediate turnaround of critical jobs). Also, resource management functions (such as job request management, job scheduling, process management, accounting and resource subsystems) are quite diverse and closely interrelated. Grant applications are sought to develop batch queue management software for large clusters. Areas of interest include management of resource allocation, establishment of different batch queues with different properties, user directed assignment of tasks to particular queues, and monitoring of queue status. The research must demonstrate the potential for flexibly managing strategies to increase overall processor and resource utilization as well as managing jobs which require simultaneous access to over half the nodes in the cluster.

c. Performance Monitoring and Management Tools—An important barrier to the efficient use of large cluster systems is the inability, in present systems, to sustain more than a small fraction of peak performance on priority applications. In order to provide a higher percentage of peak performance to end users, research and development is needed to develop software and programming techniques for the more effective utilization of large cluster systems. Grant applications are sought to develop tools that will increase the ability of scientific users, writing software in Fortran, C or C++, to monitor and improve the performance of their software. Examples of important issues include memory utilization, cache performance, identification of communications bottlenecks, and optimization of data layout.

d. Portable Operating Systems—Current operating systems are not optimized for clusters with 100s to 1,000s of processors and may incorporate design elements which raise significant barriers to achieving high end user application performance. Grant applications are sought to develop improved operating systems that are based on portable methodology and that enhance the delivery of high performance to end user scientific applications in a large cluster environment.

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   http://www.ccic.gov/pubs/blue00/BlueBook2000.pdf)

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   http://www.sc.doe.gov/production/octr/index.html

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PROGRAM AREA OVERVIEW - ENERGY EFFICIENCY AND RENEWABLE ENERGY

http://www.eren.doe.gov

The mission of the Office of Energy Efficiency and Renewable Energy (EE) is to lead the nation to a stronger economy, a cleaner environment, and a more secure future through development and deployment of sustainable energy technologies. EE develops technologies that protect the environment and support the nation's economic competitiveness through a program of research, development, and market deployment using private sector partnerships. EE is organized around the four main energy users--utilities, industry, transportation, and buildings--an orientation that has helped the technology development programs focus on addressing the needs of the marketplace.

It is estimated that the energy technologies and practices supported by the Energy Efficiency and Renewable Energy program have saved Americans ten to fifteen billion dollars in energy costs over the past decade. These savings continue to mount as new energy technologies developed by the program for buildings, transportation, utilities, and industry are put to use and as research continues. These energy savings are accompanied by parallel reductions in the emission of pollutants that affect human health and in the production of greenhouse gases. The EE program in renewable energy has advanced the state of technologies in such areas as solar, wind, and biomass to the point where renewables have been projected to supply as much as 28 percent of the nation's energy by 2030.

27. ZERO NET ENERGY BUILDINGS

Buildings account for $222 billion annual energy cost, using 36 percent of the nation's energy resources and two thirds of all electrical energy consumed in the United States. Because buildings are typically used for 50 to 100 years, their long useful life has a major impact on future energy use patterns. Recognizing this enormous impact, the U.S. Department of Energy (DOE) seeks to combine solar energy technology with energy-efficient construction techniques to help create a new generation of cost-effective buildings that have zero net annual need for fossil fuel energy. Although some zero net energy buildings have already been completed, the challenge is to make them cost-effective and affordable. Widespread construction of these buildings would contribute significantly to U.S. economic and environmental health. DOE seeks the development of several products critical to zero net energy buildings with the goal of developing optimized cost-effective designs. **Grant applications are sought only in the following subtopics:**

a. Development of Building Integrated Solar Heating and Cooling Systems—Solar space heating systems have not become commercialized or widely used in the United States because they are used only in winter. The economics of solar space heating would improve dramatically if the systems were also used for space cooling, and the integration of these technologies could extend the geographic and climate regions in which they are effective. Synergistic benefits could accrue if waste summer heat from a solar energy system was used to increase the amount of dry air produced by desiccant cooling system. In combination with the savings from winter heating, the cost of building heating and cooling could be substantially reduced. Grant applications are sought for heating and cooling systems that integrate solar thermal heating systems with desiccant cooling systems. Proposed systems must have an annual combined heating and cooling coefficient of performance above 3.0 with respect to primary energy use and be capable of efficient operation in most regions of the United States. It is also expected that grant applications will take advantage of recent European research on these "combisystems," as well as recent advances in solar heating and desiccant cooling technologies.

b. Smart Energy Management Control Systems—Grant applications are sought for smart energy management control systems that optimize the use of renewables and energy efficiency measures in zero energy building applications. Proposed systems should seek to incorporate programmable and "intelligent" microprocessor controls that provide such capabilities as: (1) utilization of predicted and/or monitored diurnal and seasonal weather and energy usage patterns (to optimize the use of renewable and conventional energy supplies); (2) computerized control over active and passive renewable energy sources (for maximum electrical and thermal output and utilization, including time of day usage); (3) dedicated end use control of renewable energy supplies (to maximize their utilization in meeting the energy needs of zero energy buildings); (4) capabilities for controlling the

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energy storage and utilization of multiple renewable energy supply systems (such as solar thermal, photovoltaic, wind, concentrating solar power, fuel cells, geothermal, micro-hydro, and biomass) for maximum energy collection and usage; (5) capabilities for controlling multiple energy efficiency measures (such as passive solar devices, windows/curtains, and building equipment and appliances) to minimize building energy loads; (6) control of energy usage during power outages (in order to maximize electric availability and utilization of real-time renewable energy collection and/or storage) to meet the selective and critical energy needs of building systems and equipment; and (7) the selective and optimal matching of DC renewable energy supply to AC powered building equipment and appliances for maximum energy utilization.

c. Low-loss Thermal Distribution Systems—The efficient distribution of thermal energy for space heating and cooling is a critical requirement of zero energy buildings. Research over the past decade has identified a number of serious deficiencies associated with duct systems in residential and light commercial buildings. One of these problems, duct leakage, has received considerable attention. However, the problem of inadequate duct insulation has not yet been adequately addressed. Part of the problem is that the vast majority of installed ductwork has a nominal thermal resistance of R-4 or less. Even the best commercially available flexible ductwork for residences has an R-value of 8, which should be compared to ceiling insulation levels of R-19 to R-38. In addition, the thermal losses through the ductwork are further exacerbated by the low air velocities within the duct, an effect that is being made increasingly important by the increased use of variable-speed fans and variable capacity HVAC equipment. Grant applications are sought to develop high-R-value ductwork while accounting for such practical considerations as ease of installation, size limitations on duct pathways, cost, and safety and code constraints. Proposed solutions must also account for the tradeoff between ease of installation, adequate insulation, and consistent airflow performance. Duct flexibility is needed to facilitate the installation process, and smooth interior surfaces and smooth bends are needed to facilitate low pressure drops and consistent airflow performance.

d. Moisture-Resistant Stucco Finishes for Buildings—Portland cement-based stucco offers the potential for low-cost exterior and interior finish systems for building construction, providing thermal mass characteristics that enhance the potential for zero net energy buildings. The material components can be easily mixed and the resulting slurry can be pumped and applied with spray equipment. Ideally, the stucco would provide water and air resistance as well as structural strength, which is particularly beneficial for designs with walls made of dry stacked block or layers of fill material contained in a porous enclosure. However, moisture uptake is a problem because moisture can go through the stucco and wet organic structural and fill material, thereby causing them to rot and decay. Although coatings have been used to address the problem, they have had to be frequently reapplied, thus increasing maintenance cost. Improved stucco materials would allow for increased use of recycled and sustainable materials for insulated wall construction and would reduce the use of wood. Building durability would be greatly increased, and the improved thermal mass and reduced thermal conduction would enable passive and active energy sources to provide a majority of the space heating and cooling energy for the building.

Grant applications are sought for additives or coatings that would make Portland cement-based stucco both waterproof and breathable, resisting rain but allowing water vapor to escape so that the building envelope materials remain dry. The additive or coating must be cost-effective, environmentally friendly, and durable, with a lifetime of at least 20 years in normal climatic conditions throughout the United States. Proposed projects (Phases I and II) must include the development of the additive or coating system, laboratory measurements of key performance indicators (moisture resistance, water vapor permeability, and structural properties of the resulting stucco), and field trials conducted on actual walls in a variety of climates.

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(Also available at http://www.aec.at/verz/english/cosys1.html) (In USA available from William A. Beckman. E-mail: beckmam@engr.wisc.edu)

28. LOW COST POWER ELECTRONICS AND SENSORS FOR DISTRIBUTED ENERGY RESOURSES

The emergence of new sources of electricity (such as ultra-clean natural gas or biodiesel engines, microturbines, fuel cells, small modular biopower, geopower packaged as cogeneration units, small wind, and customer-sited solar) is fundamentally changing the way we produce and distribute electrical energy services. Historically, electricity traveled in only one direction -- from the central power plant to the customer. In the future, customers with Distributed Energy Resources (DER) may be sending electricity back to the power company or into the grid. Better electronics and sensor technologies will be needed to insure that the electric grid can move power throughout the system to meet the needs of all connected customers. In particular, power electronic control subsystems and sensors must be developed so that future electric distribution grids will have more accurate and up-to-date information about the status of their energy providers and customers. These subsystems and sensors currently account for as much as one-third of the cost of DER systems, and innovations are needed to lower cost, increase reliability, and increase energy-efficiency without sacrificing performance. **Grant applications are sought only in the following subtopics:**

a. Small Modular Power Converters—The systems and equipment for future DER technologies will be smaller than components in use today, and the development of compatible power conversion technology will be required. However, current power conditioning and conversion systems (inverters and rectifiers) for DER are both expensive and limited in power capability. Grant applications are sought to develop small (for applications of less than 250 kW), modular, reduced-cost, inverter and rectifier systems and to increase their performance and ease of use, toward a goal of completely packaged "plug and play" systems. One possible approach would build upon techniques developed for Power Electronic Building Block (PEBB) modules (e.g., thin pack), funded by the DOE and the Office of Naval Research (ONR) PEBB Program for electric vehicles and other applications. Grant applications should focus on power conditioning needs for small (single phase) customer-sited DER technologies such as photovoltaics, small wind, electric storage, small fuel cell, and micro turbine applications.

b. High Power Converter Design—For high power DER needs, existing converters are large, expensive, and difficult to control. Typical high-power, grid-tied converter designs are based on decades-old Gate Turn Off (GTO) thyristor topologies that use complex transformer arrangements to form a stepped wave voltage output. However, state-of-the-art designs for high-power conversion, using new multi-level and Pulse Width Modulation (PWM) techniques, are currently too costly. Nonetheless, these new designs offer the potential to reduce transformer costs and system size, and they are becoming more practical due to new developments in power semiconductor devices. Therefore, grant applications are sought to develop three-phase power converters with significantly reduced installed cost/KVA and footprint, and significantly improved control capability, in high power, grid-tied energy storage and distributed resource systems. Grant applications must address one or more of the following applications: utility level energy storage, power quality or peak shaving, and distributed generation. Also, the converters must be suitable for systems with ratings in the following ranges: 4.16-24 kVA and 2-10 MVA. Grant applications must include a design study featuring system modeling, conceptual design layout, initial cost estimates, identification of system advantage, and a detailed comparison with a suitable existing system.

c. Customer Status Sensors for DER—Currently, there are no simple and inexpensive means to determine the on-line status of customer-sited DER equipment in real time. Although large industrial customers can install custom design interfaces with the electric utility, there are no comparable low cost technologies suitable for commercial and, eventually, residential customers that might choose to install on-site power generating equipment. Grant applications are sought to develop low cost sensors to determine the electrical condition (including power quality) of the power line (voltage, current, temperature, etc.) and communicate data back to a collection station with minimal additional cost and/or hardware requirements. For high power applications, these sensors should monitor across all three phases and include a diagnostic capability. Proposed sensors should also provide key application-specific diagnostics (such as gas flow and pressure), must be easily installed in a non-invasive manner that does not disturb the existing infrastructure, and must be applicable to customer-sited DER.

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29. BIOPRODUCTS AND BIOENERGY RESEARCH

Energy from sunlight, our abundant natural resource, offers the opportunity to utilize a sustainable source of raw materials -- namely, biomass from our nation's crops, forestry, aquatic, and agricultural wastes -- to power our homes, fuel our vehicles, and create everyday products. The use of biomass to produce BioProducts and BioEnergy (BioP&E) will help strengthen U.S. energy security, protect the environment, reduce greenhouse gases, and revitalize rural America. The Office of Energy Efficiency and Renewable Energy, including the Office of Transportation Technologies, the Office of Industrial Technologies, and the Office of Power Technologies, seek environment friendly technologies that enable bio-based renewable resources to produce home-grown transportation fuels, chemicals, materials or consumer products, and generate clean locally-based power. Grant applications must demonstrate that proposed approaches have the potential to be more economical than currently practiced technologies. **Grant applications are sought only in the following subtopics:**

a. Modular Power Systems Using Farm Animal Wastes—Large quantities of manure, generated at poultry, swine, and dairy farms, are causing high levels of environmental degradation by polluting the nation's vital watersheds. Various states are exploring ways of disposing of farm animal wastes and are in the process of enacting laws to prohibit many current handling practices. Because animal

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manure is a potential source of energy, the conversion of animal wastes to energy and other high-value by-products would not only add value but also address the environmental pollution problem. Grant applications are sought to develop modular systems based on thermochemical processes such as combustion, gasification, and pyrolysis to economically convert farm animal wastes primarily to electricity and also to heat as a by-product. In this context, the term modular refers to small (few kW to few mW), integrated systems that can be factory-fabricated and mass produced to lower capital equipment costs. In addition to being small and modular, proposed systems must also be fuel flexible, efficient to operate, and have minimum negative impact on the environment. Modular systems of interest could include, but are not limited to, the utilization of such technologies as advanced fuel cell systems, Stirling engines, and micro-turbines. The Phase I feasibility study must include a preliminary market and resource assessment, preliminary tests to determine material and energy balances, a preliminary integrated system design, preliminary cost estimates (including electrical interface costs) to compare costs with traditional disposal/conversion methods, and estimates of environmental emissions and benefits. Projects should be planned in partnership with appropriate stakeholders (such as farmers, power producers, equipment suppliers, and state authorities) to provide solutions for area or region specific problems.

b. Biomass Material Handling—A major barrier to the market penetration of bioenergy and biobased product technologies is the high cost of handling the diverse biomass resources, which include both residues and crops. Residues include urban wood wastes, agriculture residues (such as corn stover), farm animal wastes, forest residues, etc. Crops include hardwood and grasses such as willow, poplar, switch grass, etc. Biomass material management starts with the harvest or collection of biomass resources, continues with processing and drying, and ends with feeding the processed biomass to units (e.g., for combustion, gasification, pyrolysis, or other processing) for the generation of power or for integration with chemical processes for the production of fuels and/or biobased products. Grant applications are sought for equipment or processes that address the reduction in handling cost in the areas of material collection technologies, innovative harvesting technologies, moisture removal approaches, densification technologies, storage approaches that minimize degradation, and novel approaches for transportation. Because different resource handling and utilization strategies would be appropriate for different biomass sources and different power generation, fuel production, and biobased product production schemes, grant applications must specify the bioenergy or biobased product technology and the biomass resource type(s) that are being considered and provide an analysis to determine the cost saving.

c. Production of Energy Efficient Low-Cost Sugar—Plant matter is rich in carbohydrates that can be broken down to C6 and C5 sugars (i.e., glucose and xylose), important intermediate chemicals in the conversion of biomass to biobased products and energy. With further chemical processing, i.e., fermentation, these sugars can serve as feedstocks for higher chemicals and fuels. However, the cost of producing these sugars is a major obstacle to the widespread use of biomass products and energy. If the cost of producing fermentable sugars could be reduced, there would be a tremendous increase in the use of renewable carbon (biomass) in place of fossil carbon for the manufacture of fuel, chemicals, and materials, and this would spur the development of bio-refineries. Although prior research has led to some promising processes (e.g., cellulose technology, dilute acid hydrolysis, and other hydrolysis schemes), further improvements or entirely new processes are required. Therefore, grant applications are sought to develop a more cost-effective and energy efficient process to produce C6 and/or C5 sugars from plant matter.

d. Clean-Up of Gases from Gasification Processes—Biomass gasifiers, which would operate upstream of either gas turbines or fuel cells, require further gas processing to improve gas quality to the tolerance level of the power generation device. However, hot gas cleanup for turbine injection presents difficulties in removing particulates and corrosives. Fuel cell requirements are even more demanding. Grant applications are sought to develop novel cleanup methods that could greatly enhance the potential use of biomass gasifiers with turbines and fuel cells. The Phase I feasibility study must include a preliminary application and resource assessment, preliminary tests to determine material and energy balances, a preliminary integrated system design, cost estimates, and estimates of environmental emissions and benefits.

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* See Section 7.1

** Available at http://www.oit.doe.gov/agriculture/pdfs/af25942.pdf

30. HEAT TRANSFER RESEARCH

Improvements in the heat transfer ability of working fluids in thermally-based energy systems can lead to increased conversion efficiencies, lower pollution, decreased costs including operation and maintenance costs, improve reliability, and could facilitate the miniaturization of energy systems. This topic explores several approaches to improved heat transfer. In the power generation industry, the properties of heat transfer fluids (HTF) could be improved by using nanoparticle additives. In buildings, new liquid desiccant air conditioning systems offer advantages over the more widespread solid systems, and new enthalpy exchangers can improve the energy-efficient conditioning of ventilation air. **Grant applications are solicited only in the following subtopics:**

a. Metallic Nanoparticles in Traditional Heat Transfer Fluids—Because metallic solids have thermal conductivities that are orders of magnitudes greater than the liquid HTFs currently used, a suspension of ultra-fine metallic particles in a traditional HTF may dramatically improve its energy transfer ability. However, until recently, the smallest available particles were of micron size and could not be used in heat transfer equipment due to severe clogging (agglomeration) in smaller passageways. Therefore, grant applications are sought to develop new "nanofluids," in which metallic particles of nanometer dimensions are suspended in traditional heat transfer fluid. Candidate nanofluids must be evaluated with respect to the most important HTF characteristics (high specific heat, high density, low cost, low freezing point, and non-corrosivity) and must be compatible with the applications envisioned. As a starting point, grant applications should utilize the existing body of knowledge on the characteristics and limitations of metallic nanoparticles, in order to identify candidate metallic nanofluids based on the above characteristics.

b. Non-Metallic and Other Novel/Exotic Materials for Nanofluids—In addition to metallic nanoparticles, other nanoparticle materials may offer certain advantages as HTF additives. For example, some non-metallic solids, such as silicon, are far less reactive with certain HTFs than metallic solids. Completely new materials and structures (e.g., "Buckyballs" and materials "doped" with additives in their molecular structure) also may have desirable characteristics. Grant applications are sought to develop heat transfer fluids that utilize non-metallic or other novel/exotic nanoparticles. Proposed efforts should develop performance data to identify suitable pairs of candidate additive materials and HTFs, and to demonstrate the following desirable characteristics: high specific heat, high density, low cost, low freezing point, non-corrosivity, and ability to perform within a range of operating temperatures.

c. Low-Maintenance, High-Efficiency Liquid Desiccant Regeneration—Although solid desiccant air-conditioning technologies have achieved commercial success in applications such as supermarkets and schools, liquid desiccant systems have been used only in industrial markets, primarily due to their higher cost and maintenance requirements. However, liquid desiccant systems offer some unique advantages including distributed conditioning with centralized regeneration, biocidal capability, and potentially higher energy efficiency. For example, the thermal Coefficient of Performance (COP) for typical solid desiccant-based cooling devices is below 1.0, whereas liquid desiccant regenerators promise COPs of at least 1.3. (Regenerator COP is the ratio of the heat needed to boil a quantity of water removed from the desiccant to the heat supplied to the regenerator, measured at the American Refrigeration Institute's rating condition for air conditioning.) Grant applications are sought for new liquid desiccant regenerators that can realize the potential for liquid technology to maximize energy savings, make the transition to commercial markets, and require much less maintenance. Areas of research interest include the incorporation of waste heat recovery with vapor-compression regeneration, the development of methods to effectively address non-condensables in multiple-effect boilers, and the development of zero-maintenance techniques for preserving desiccant charge in evaporative regeneration stages. Grant applications must also address maintenance needs, and proposed maintenance schedules must be suitable for commercial and, eventually, residential markets.

d. Low-Cost, High-Performance Enthalpy Exchangers—Energy recovery (sensible and latent) from building air is an attractive approach to the energy-efficient conditioning of ventilation air. The removal of latent heat can reduce the high moisture loads sometimes found in outdoor air during the cooling season. If the latent heat is not removed, occupant comfort and health are degraded due to

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high humidity levels and the resulting increase in emissions from microbial activity (spores and toxins from molds, fungi, etc). Because this removal is difficult with conventional cooling equipment, grant applications are sought to develop total energy recovery devices (enthalpy exchangers) and to extend these energy saving features to the broadest, most cost-sensitive building markets possible. Proposed designs must not compromise system performance (i.e., sensible and latent effectiveness and pressure drop) and must achieve sensible effectiveness of 75 percent and latent effectiveness of 65 percent at the American Refrigeration Institute's rating conditions for enthalpy exchangers. The pressure drop on either side must be no more than 0.8 inches of water. All performance criteria must be met at a nominal face velocity of 600 feet per minute. Areas of research interest include accelerated desiccant coating/impregnation techniques, durability enhancements for low-cost substrates, and heat/mass transfer enhancements for low-cost core geometries.

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31. RECOVERY, RECYCLE, AND REUSE OF ENERGY INTENSIVE MATERIALS

The energy and environmental benefits of recycling are significant. Accordingly, an infrastructure presently exists to support the recycling of certain commodity materials, especially metals, from a variety of sources such as industrial scrap and consumer durables (e.g., automobiles, appliances, and computers). For example, steel and aluminum are currently recycled at rates in excess of 60 percent. The recycling of these materials, along with paper and glass, are

estimated to conserve 1.5 quad of energy per year. Recycling polymers and plastics could save a comparable amount of energy, yet the total recycle rate of these materials is less than 2 percent. Although some plastics, such as high-density polyethylene (HDPE) from beverage bottles, are successfully recycled, new technologies and approaches are required to increase the recovery, identification, and re-use/recycle of polymers and plastics used in industrial and consumer durables applications. Grant applications related to the collection/transportation of materials for recycling and technologies for conversion of organic materials to energy (e.g., waste-to-energy) are outside the scope of this topic and will be declined. **Grant applications are sought only in the following subtopics:**

a. Materials Recovery and Identification—New technologies and processes are needed to cost-effectively recover plastics and polymers from industrial waste streams and from bulk durable such as automobiles. As long as the materials have not degraded in use, the availability of such processes would permit their reintroduction into markets now being served by virgin resins. Grant applications are sought for low cost, efficient processes to separate polymer-containing material from other material, polymers from each other, and non-polymeric impurities (e.g., colorants, sealants, and fillers) from a given polymer.

As plastics have become more prevalent in structural applications, the use of fibers and fillers to increase mechanical properties has become more common. Where the fibers or fillers have significant value (e.g., carbon fibers), their recovery could have significant economic benefits. Therefore, grant applications are also sought to develop techniques for recovering these fibers or fillers, while maintaining their desirable properties. Of particular interest are fiber/filler recovery approaches that would also simplify the recovery or conversion of the remaining plastic materials.

Lastly, grant applications are sought to develop innovative chemical approaches for the recovery of monomers and chemical precursors from plastics. Of particular interest is the use of chemical conversion and chemical modification to recover relatively high purity monomers from waste streams of single polymer or polymer blends.

b. Re-Use and Conversion of Recovered Plastics and Polymers—Oftentimes, plastics and polymers cannot be directly re-used, because aging effects from long-lived first applications may have changed the nature of the material, because residual contaminants in the recovered material may not be cost-effectively removed, or because the recovered material cannot be directly reprocessed, such as with thermoset plastics. Therefore, grant applications are sought to develop viable uses and markets for recovered plastics, mixed plastics, and polymers. Proposed efforts must demonstrate that the new uses/markets will (1) absorb a large volume of material at acceptable economics, and (2) provide significant energy savings in terms of reduced crude oil imports. The latter saving could come about by direct replacement of virgin resin, reduced use of other energy-intensive materials, or extensions in the useful life of petroleum based products. Where the recovered material itself is not useful (such as for polymer mixtures that have undergone gross phase separation and/or residual contamination), the proposed effort must develop technologies and processing techniques to make it more useful; possible approaches include physical processing, the use of additives, and/or chemical reactions that act on the mixture to convert one or all components of the mixture to value added chemicals/products.Areas of interest include the use of recycled polymers as asphalt additives and as cement and concrete additives.

c. Silicon Recycling—Silicon technology is at the core of photovoltaics (PV) and many other energy related commercial applications. For example, crystalline silicon accounted for of 87 percent of the worldwide PV module shipments in 1997. Although the unprecedented growth in semiconductors has brought significant advances in Si-based technologies, the PV Si industry is still not growing as fast as predicted, mainly because of the high cost and unavailability of raw materials. In the last five years, the price of polysilicon has almost doubled, and shortages have occurred. If production of polysilicon does not increase substantially, shortages of this material may become an acute problem and impact the ability of the U.S. to maintain its current leadership in solar device production. One untapped source of polysilicon is the waste produced from sawing Si ingots and processing wafers. When wafers are sliced from silicon ingots using a multiple-wire saw, a layer of silicon about 250 micrometers thick is lost per wafer (even higher for inner-diameter saws). Depending on the wafer thickness, this kerf loss represents from 25 percent to 50 percent of ingot material, several times the amount that is presently used by the PV industry. Potentially, enough polysilicon could be generated for over 300 MW/year of crystalline-silicon solar cells. Therefore, grant applications are sought to develop techniques for producing solar-grade polysilicon by purifying the kerf remains of semiconductor-grade ingots.

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32. REACTIVE SEPARATIONS

Reactive separations utilize close coupling of separation and chemical reactor systems, often in a single unit, to improve the yield of the reaction, the production of desired products, and/or to lower energy consumption and capital investment. Reactive separation systems may take many forms and may not resemble conventional chemical reactors and separations equipment. Reactors could be catalytic or homogeneous, continuous or batch. Any separation method could be used including adsorption, distillation, or extraction. A simple example of a reactive separation is a tubular reactor that utilizes a selective membrane tube filled with catalyst. The membrane selectively permeates a desired reaction product, and the removal of that product along the reactor length continuously shifts the chemical equilibrium among the potential products and reactants, increasing both the utilization of reactants and the production of the desired product.

Improvements from combining separations and chemical reactor operations can be substantial. In conventional systems, the yields of desired products are often limited by the equilibrium constant, and a product's concentration is usually determined by a thermodynamic equilibrium distribution of products and reactants. By combining a reactor with a separation operation that removes the most desired product, as in the above example, the utilization of reactants can be improved, and the reaction can provide significantly higher yields of the most desired product. Energy savings can also be realized when products from one reaction step can be separated and used as reactants in a second reaction step. When one reaction step is exothermic and the other reaction is endothermic, the energy from the exothermic reaction can be used to drive the endothermic reaction.

Unfortunately, effective reactive separation systems usually are highly system-specific, and particular combinations of separation and reactive systems are required for each potential application. For numerous low yield systems, no effective reactive separation systems are likely to be found. (Part of the difficulty is that reactive separation systems not only must include both reactor and separation capabilities, but also both functions must take place at approximately the same temperature and pressure, at least if they are to be incorporated in the same equipment.) Therefore, each grant application must identify a particular application -- one with the potential for large savings of energy and materials, and/or for significant reduction in waste products. Grant applications targeting new and/or improved processing of radioactive wastes (i.e. high level waste, spent nuclear fuel, low level wastes, etc.) will not be considered under this topic. Also, grant applications aimed at demonstrating reactive separation systems that have been studied extensively in the past, or those limited to testing a particular system under a specific set of conditions, are not of interest and will be declined.

Proposed efforts should not only be innovative, but also should seek to understand the dynamics of the reactive separation system. Grant applications must explain how or why the proposed reactive separation concept would result in improved raw material utilization (reactor yield) and energy savings compared to current (or currently proposed) approaches to producing the target products. Grant applications should also address the likelihood of further

development or commercialization beyond Phases I and II (e.g., by identifying particular industries, government agencies, or even companies, that not only would benefit from the technology development but also may contribute follow-on funding). **Grant applications are sought only in the following subtopics**:

a. Reactive Distillation—Forty thousand distillation columns are used today in manufacturing 90 to 95 percent of all products in the continuous process industries. Advances in distillation could increase productivity, reduce costs, enhance product purity, and increase overall energy efficiency. Reactive distillation offers the possibility of reducing capital costs by combining reaction and distillation in one process step. The best candidate reactions involve reversible exothermic reactions with favorable kinetics at temperatures of separation. Several reactive distillation processes for the preparation of ethers, such as ethyl tert-butyl ether (ETBE) and tert-amyl methyl ether (TAME), have been commercialized already, and efforts to broaden the application of reactive distillation to other reaction systems have begun. However, the advantages of reactive distillation can be off-set by kinetics, equilibrium, and mass transfer issues, catalyst placement, and the compatibility of separation and reaction conditions for a given system. Grant applications are sought to adopt the reactive distillation process to other reversible exothermic reaction systems to improve energy efficiency and product yield. Proposed efforts must provide an understanding of process fundamentals and show how and why the above technical barriers will be overcome.

b. Membrane Reactors—Membrane reactors have been proposed in a variety of configurations employing polymeric, ceramic, metallic, or liquid membranes for coupling and combining process reactions and separations. The membrane reactors can improve process performance through equilibrium shifts, reducing product inhibition, the use of catalyst activated membranes, etc. However, to be competitive with conventional technologies, membrane reactors must be shown to have superior economics (e.g., reduced material and energy intensity, lowered pollutant dispersion) over a full life cycle. Grant applications are sought to develop improved membrane reactors for particular applications with outstanding economics compared to existing technology. Proposed efforts must include the development of membrane reactor materials with improved reliability and performance (e.g., better selectivity, permeability, stability) as well as the development of unique approaches for engineering the membrane contacting devices. Grant applications that simply apply membrane technology to existing reactor processes are not of interest and will be declined; rather, proposed efforts must identify and exploit new, more efficient chemical pathways that membrane reactors would make possible.

c. Reactive Separations for Waste Reduction—Most industrial interest in reactive separations is due to its potential to increase product yields and improve the economics of a number of important synthesis processes. However, the increased product yield also provides an opportunity for decreasing waste generation. Grant applications are sought to develop reactive separation systems, other than reactive distillation and membrane reactors, which provide significant reductions in waste generation and pollutant dispersion. Areas of interest include reductions in net CO_2 production, solvent use, and the release of persistent, bio-accumulating, toxic materials into the environment.

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PROGRAM AREA OVERVIEW - BASIC ENERGY SCIENCES

http://www.er.doe.gov/production/bes

The Basic Energy Sciences (BES) program supports fundamental research in the natural sciences leading to new and improved energy technologies. The program's purpose is to create new scientific knowledge by supporting basic, peer-reviewed research in areas of materials sciences, chemical sciences, geosciences, plant and microbial biosciences, and engineering sciences that are relevant to energy resources, production, conversion, and efficiency. The results of BES-supported research are routinely published in the open literature.

A key function of the program is to plan, construct, and operate premier national user facilities to serve researchers at universities, national laboratories, and industrial laboratories, thus enabling the acquisition of new knowledge that cannot be obtained in any other way. The scientific facilities include synchrotron radiation light sources, high-flux neutron sources, electron-beam microcharacterization centers, and specialized facilities such as the Combustion Research Facility. These national resources are available free of charge to all researchers based on the quality and importance of proposed nonpropriety experiments.

A major objective of the BES program is to promote the transfer of the results of our basic research to advance and create technologies important to Department of Energy (DOE) missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, mitigation of the adverse impacts of energy production and use, and future fusion energy sources. The following set of technical topics represents one important mechanism by which the BES program augments its system of university and laboratory research programs and integrates basic science, applied research, and development activities within the DOE.

33. CATALYST APPLICATIONS AND ENABLING SCIENCE FOR CHEMICAL MANUFACTURE

About 90 percent of chemical manufacturing processes and more than 20 percent of all industrial products in the U.S. employ underlying catalytic steps. For example, catalysis plays a substantial role in the production of 30 of the top 50 U.S. commodity chemicals. Six more of the remaining 20 are made from raw materials that are produced catalytically. The energy use component in the production of the top 50 chemicals is significant -- 5 quads per year -- 3 quads per year for those with catalytic production routes. It has been estimated that if all the catalytic processes associated with the top 50 chemicals were raised to their maximum process yields, total energy savings would exceed 0.47 quads per year. Even a more realistic process-yield improvement of 10 percent would save 0.23 quads per year. In addition, more efficient chemical production, resulting from improvements to catalytic processes, would also contribute to significantly reduced carbon emissions. For the top 50 chemicals, over 20.9 billion pounds of CO_2 are produced either directly or via unwanted carbonaceous byproducts that are later incinerated or biologically converted. This topic seeks to accelerate the catalyst discovery and applications process by identifying catalysts that have higher selectivities, can operate at modest temperatures and pressures, and contribute to a reduction in the number of unit operations, all of which impact overall resource efficiency. **Grant application are sought only in the following subtopics:**

a. Alkanes and C1 Compounds as Feedstocks—The efficient conversion of alkanes and C1 compounds directly to higher value chemicals, without intermediate steps, could yield large energy savings. For example, olefins, which dominate as building blocks for commodity chemicals and polymers, are derived from alkanes in energy intensive processes. Likewise, many C1 compounds occur naturally (such as methane), are produced as byproducts, or are contained in industrial emissions; potentially, these compounds could be recovered for use as inexpensive feedstocks. Grant applications are sought to develop new catalysts for producing high value chemicals using alkanes and C1 compounds as feedstocks. In addition, grant applications must focus on one or more of the following areas of interest: (1) understanding how catalysts such as metals, metal oxides, and transition metal complexes influence the activation of C-H bonds; (2) novel pathways for the selective conversion of methane to higher molecular weight products; (3) new catalysts for selective synthesis of chemicals from CO, and (4) C1 chemistry for the production of monomers.

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b. Oxidation Catalysts—Oxidation is the most energy intensive of all chemical processes for the production of commodity chemicals and polymers. These commodity chemicals include ethylene and propylene oxide, styrene, phenol and acetone, and nitric acid. More selective oxidation could reduce energy consumption by increasing the yield of desired compounds. Grant applications are sought to develop catalysts and associated processes for the oxidation of alkanes, olefins, and aromatics.

c. Solid Acid and Solid Base Catalysis—Acid and base catalysts are important throughout the petroleum refining and chemical processing industries -- from the upgrading of refinery feedstocks to the production of subsequent chemical derivatives. For example, acid catalysts are commonly used in alkylation, where small hydrocarbon molecules are joined to form larger molecules. The most common of these is the Friedel-Crafts alkylation process, using hydrofluoric acid or aluminum chloride. Catalysts such as these are highly corrosive, posing a significant environmental concern. Grant applications are sought to develop: (1) viable solid acid and solid base catalysts to replace toxic and volatile mineral acids and bases; (2) solid acid alkylation catalysts with sustained activity at low temperatures; (3) techniques for regeneration of deactivated solid acid catalysts; (5) methods for reducing coking on solid acid catalysts; and (6) new, cost-effective ways of synthesizing solid acid and solid base catalysts.

d. Homogeneous Catalysis—Over the past several years, industrial R&D has brought about a revolution in homogeneous catalysis for the preparation of both new polymer materials and oxygen- and nitrogen-containing organic compounds. These processes carried out with higher selectivities and at lower operating temperatures and pressures than possible with some heterogeneous catalytic synthetic processes. Product yields are also improved with homogeneous catalysts. For example, industrial acetic acid is now made almost exclusively from synthesis gas using a homogeneous catalyst, instead of using ethylene at elevated temperature and pressure. Grant applications are sought to develop homogeneous catalysts and associated processes for the preparation of new polymer materials and for the synthesis of important oxygen and nitrogen compounds. Of particular interest are proposed approaches for the development of new classes of homogeneous catalysts (i.e., those not based on precious metals such as rhodium).

Grant applications are also sought to combine homogenous catalysis with separations processes in the preparation of industrially important chemicals. Although such combined reaction and separation processes have been attempted (for example, immobilizing homogeneous catalysts on membranes), they have met with limited success due to the solubility of the catalyst.

For all grant applications, the catalysts must demonstrate viability for the synthesis of industrially important organic chemicals at high selectivity and at moderate temperature and pressure conditions (chosen to optimize energy utilization).

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34. MEMBRANES FOR ADVANCED INDUSTRIAL SEPARATION TECHNOLOGIES

Industrial separations recover, isolate, and purify products in virtually every industrial process. Pervasive throughout industrial operations, conventional separation processes are energy intensive and costly. Separation processes represent 40 to 70 percent of both capital and operating costs in industry. They also account for 45 percent of all the process energy used by the chemical and petroleum refining industries every year. Industrial efforts to increase cost-competitiveness, boost energy efficiency, increase productivity, and prevent pollution, demand more efficient separation processes. In response to these needs, the Department of Energy supports the development of high-risk, innovative separation technologies. In particular, membrane technology offers a viable alternative to conventional energy intensive separations.

Successful membrane applications include producing oxygen-enriched air for combustion, recovering and recycling hot wastewater, volatile organic carbon recovery, and hydrogen purification. Membranes also have been combined with conventional techniques such as distillation to deliver improved product purity at a reduced cost. Membrane separations promise to yield substantial economic, energy, and environmental benefits leading to enhanced competitiveness by reducing annual energy consumption, increasing capital productivity, and reducing waste streams and pollution abatement costs.

Despite the successes and advancements, many challenges still face the adoption of membrane technology. Technical barriers include fouling, instability, low flux, low separation factors, and poor durability. Advancements are needed that will lead to new generations of organic, inorganic, and ceramic membranes. These membranes require greater thermal and chemical stability, greater reliability, improved fouling and corrosion resistance, and higher selectivity. The objective is better performance in existing industrial applications, as well as opportunities for new applications. To advance the use of membrane separations across the energy intensive industries research is needed to develop new, more effective membrane materials and innovative ways to incorporate membranes in industrial processes. **Grant applications are sought only in the following subtopics:**

a. Membrane Materials with Improved Properties—Grant applications are sought to develop lower cost membrane materials in order to improve the following properties: (1) increased surface area per unit volume, (2) higher temperature operation (e.g., by using ceramic or metal membrane materials), (3) suitability for separating hydrophilic compounds in dilute streams, (4) ability to separate by differences in chemistry, size, and/or diffusivity, and (5) capability to reverse separation order. All grant applications must address one or more of the particular types of membrane materials listed below and one or more of the particular processes/systems, which are also listed below. The particular membrane materials of interest are nano-composites, mixed organic/inorganic composites, and chemically inert materials. The particular processes/systems of interest are small volume oxygen production; oxygen separation/oxidative chemistry; oxidation/dehydrogenation reactions; and membrane reactors. Proposed efforts must target specific membrane materials for carefully defined commercial applications; efforts focused on generalized membrane material research are not of interest and will be declined.

b. Enhanced Membrane Process Systems—Grant applications are sought to enhance the performance or reduce the cost of membranes that are currently used in industrial process streams. Membrane systems that are developed must be integrated with the overall unit operation and must be shown to be robust in one or more of the following real-world processes: hydrogen separation/recovery, inert gas removal, isomer separation, aromatic/nonaromatic separations, sulfur removal, and removal of trace metals. In addition, grant applications must address one or more of the following needs: (1) techniques for overcoming scale-up problems related to contaminants in industrial streams (fouling, oil misting, etc.), (2) development of scalable low-cost membrane manufacturing techniques, (3) development of manufacturing technologies that would reduce the cost of

membrane modules, (4) improvement of long-term operability of membranes systems with anti-fouling and anti-flux declining schemes, and (5) methods to regenerate membrane performance and lower membrane maintenance costs. Along with the R&D effort, grant applications also must include a process evaluation and an economic analysis for the integrated membrane system.

c. Membrane Separations for Dilute Streams—Grant applications are sought for improved or novel approaches for developing cost-effective membranes to separate, and then recover or remove components from dilute gaseous streams, dilute aqueous streams, or both. The research objectives must include the recovery of valuable components or the removal of contaminants from a useful or recyclable stream, or from a stream that will enter the environment. One or more of the following dilute streams must be addressed: paraffins/olefins, H_2O/ethanol, CO_2/natural gas, sulfur/natural gas/liquefied petroleum gas/oils, SO_2/air, organics/air (e.g., VOCs), organics/water, metals/water, metals, oil, and solid particles in air/water.

d. Membrane Separations for Bioproducts and Bioenergy—The processing of bio-based renewable resources to make chemicals and fuels requires improved separations technology to save energy, improve product yields, and decrease waste. These separations are particularly critical in fermentation processes. Fermentation productivity is frequently limited by the buildup of the desired product or unwanted material in the fermentation media as the fermentation proceeds. This buildup can adversely affect the fermentation microorganism, resulting in either slowing down its metabolism or reducing its selectivity. For example, in fermentation processes to produce organic acids, such as lactic acid or succinic acid, the decrease in pH resulting from the acid buildup negatively impacts the microorganism. Similarly in the fermentation of alcohols such as ethanol, the build up of ethanol negatively impacts the microorganism. If one could continuously remove these products from the fermentation media, fermentation productivity could be greatly enhanced. Therefore, grant applications are sought to develop more efficient membrane separation systems for bio-based renewable processes that will permit the separation of the desired product and/or undesired materials during or subsequent to a fermentation process to enhance the overall process productivity and reduce the energy requirement.

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* See Section 7.1

35. HIGH TEMPERATURE SUPERCONDUCTIVITY FOR ELECTRIC POWER APPLICATIONS

High temperature superconductivity (HTS), a phenomenon which permits the conduction of electricity without resistance at temperatures above the boiling point of liquid nitrogen (77 K), was discovered in 1986 and was identified as a critical technology by the 1991 National Critical Technologies Panel. HTS wires have the potential to carry 100 times the electrical current of conventional (copper) wires without energy losses, leading to advanced electrical systems that are half the size and have only half the losses of conventional systems with equivalent power ratings. HTS electric power equipment is now under development and is expected to lower the cost and pollution associated with electricity generation, delivery, and use early in the next century. A world-wide market of several billion dollars per year for superconductivity products has been predicted, and wire-dependent products will comprise the largest market share. However, substantial technical barriers remain to be overcome before the widescale commercial application of HTS becomes a reality.

Considerable progress has been made in the technology of HTS wire, generally in two primary areas: (a) powder-in-tube (PIT) processed conductors and related forms based on bismuth cuprates (BSCCO), and (b) so-called Second Generation Wire, which now consists of yittrium-barium-copper-oxide (YBCO) cuprate thick films coated on buffered metallic strips which are suitably prepared to permit a highly-controlled degree of crystallographic texture in the YBCO film. PIT-processed BSCCO wires are now commercially available, but are restricted in the ranges of magnetic field and temperature where they can be usefully employed. Therefore, this topic focuses on Second Generation Wire based on YBCO, which is considered to have much greater potential for high-field applications at liquid nitrogen temperatures. Incremental advances to current HTS technology will not be considered responsive to this solicitation. **Grant Applications are sought only in the following subtopics:**

a. HTS Coated Conductor Second Generation Wire Processing Methods—In the newer coated conductors process, metal strips are prepared, buffer layers are added, and then subsequent coatings of HTS films are deposited. If the process is optimized, the crystal structure in the HTS film will be directionally aligned and the film will carry large electrical currents. Grant applications are sought for processing innovations which will lead to lower manufacturing costs (comparable to that of low temperature superconducting wire) and will improve the performance (i.e., increased current, especially at higher magnetic fields) of coated conductors. Approaches of interest include both coating improvements and improved preparation of the underlying metal strip. Coating improvements include faster coating processes, thicker films with higher current densities, and improved uniformity in long lengths. Applicants must demonstrate a capability to fabricate long lengths of conductor (5 meters or greater) and to characterize the critical current densities of conductors adequately by the end of Phase II.

b. Processing Diagnostics for Coated Conductor Manufacture—In order to improve process control and optimization, needs exist in several areas of processing diagnostics for *in situ* and *ex situ* processed YBCO coated conductors. In particular, high performance YBCO coated conductors require close processing control of biaxial orientation and chemical stoichiometry. The ability to perform such characterization on rapidly moving tapes (~1 cm/s) would enable continuous process control and higher critical current tapes than possible with uncontrolled, batch processing of coated conductors. Grant applications are sought to develop nondestructive real-time diagnostics of moving coated-conductor tapes that can perform compositional analysis, crystalline order and texture characterization, electrical characterization, and superconductivity analysis. Conventional NDE techniques such as acoustic emission, ultrasound, and film-based radiographic testing are not considered to be applicable to

the above characterizations and analyses, and grant applications based on these techniques will be declined.

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* See Section 7.1

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36. SENSING TECHNOLOGIES FOR CORROSION PROCESSES

The U.S. Department of Energy, Office of Basic Energy Sciences is interested in understanding the passivity exhibited by a number of engineering alloys (e.g. aluminum, titanium, and stainless steel). These passive materials are used in transportation, microelectronics, electrical power production (conventional and nuclear), and hazardous waste containment. The stability of these materials is determined by the extent to which a high integrity passive oxide film forms and is retained during continuous exposure to the ambient environment. Localized corrosion due to breakdown in these thin oxide films is responsible for limiting lifetime of components made from these materials. Due to the small length scale, atmospheric corrosion is of concern for passive materials used in microelectronics and the evolving fields of micro(opto)electromechanical technologies as well as eventual nanotechnologies.

Conventional corrosion investigation techniques are limited in their ability to provide complete and detailed information about the corrosion process. Recently developed small length scale probes and sensors show considerable promise in advancing our understanding of localized corrosion. Opportunities exist in developing corrosion sensing technologies that provide information about the process of local passivity loss at appropriate length scales (100 micrometers or less).

Note: The Material Sciences Division of the Office of Basic Energy Sciences supports the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials. This is a virtual center, with members distributed throughout many research institutions, including the DOE national laboratories. The Center's project on the Science of Localized Corrosion contributed to the subject matter of this topic. Potential applicants requiring further clarification of this topic should contact:

Dr. Kevin R. Zavadil
Sandia National Laboratories
Phone: 505-845-8442
Fax: 505-844-7910
Email: krzavad@sandia.gov

Depending on the nature of the proposed research, potential applicants to this topic may want to consider taking advantage of the availability of one of the DOE user facilities. For more information, see section 1.6.2 of this solicitation. **Grant applications are sought only in the following subtopics:**

a. Multiple Element Corrosion Sensing Arrays—Grant applications are sought to develop multiple sensor arrays that provide spatially resolved information relevant to the corrosion process for aluminum, titanium, and stainless steel. Process information sought includes corrosion event location, rate, and/or relevant chemistry. Examples of techniques include optical, magnetic, electrical, electrochemical, surface potential or combinations of individual techniques. Developed techniques could be applicable to either atmospheric (ultrathin adsorbed water layers) or fully condensed phase environments. Proposed ideas must represent either new concepts or an established concept that is greatly expanded upon in terms of information content and extraction. An example of a new concept brought to the sensor level would be small length scale (less than or equal to 10 micrometers) scanning techniques that can be converted into static techniques based on an array of spatially distributed probes that preserve appropriate length scales for the passivity loss process. Priority will be given to ideas where information content can be correlated with local corrosion susceptibility and rates.

b. Noninvasive Imaging Technologies for Localized Corrosion Event Monitoring—Eventual material degradation and failure results from large-scale localized losses such as pitting in aluminum alloys and crevice corrosion in titanium alloys and stainless steel. Tools capable of tracking corrosion events on a length scale of 100 micrometers are needed for both laboratory and field studies. Grant applications are sought to develop a noninvasive, real-time imaging capability to monitor local corrosion event rates and evolving structure. Proposed techniques must measure some combination of local material loss, evolving local chemistry, and resulting pit or crevice dimension changes. Information processing may be required to extract meaningful measurements for the data. Examples of techniques yielding structural information include confocal microscopy, ultrasonic imaging, and tomographic methods. Local chemical information would also be valuable and could be generated using spectroscopic techniques. Priority will be given to ideas that show promise for real-time monitoring.

c. Integrated Corrosion Sensing Architectures and Data Processing—The effective use of corrosion sensor arrays (as described in Subtopic a), or of multiple sensors operating in different domains, will require that their output be integrated through optimized architectures and improved data processing, in order to extract a higher value information

content. Therefore, grant applications are sought to develop optimized architectures and direct data processing methods that can combine the output of multiple sensors in order to provide information on the location, rate, and chemistry of corrosion events on length scales of 10 micrometers or less. One possible approach might include triangulation techniques, using sensors from either similar or different domains, to return event location and rate information. If the proposed architecture includes the integration of sensor information from different sensing domains, they must be accompanied by associated data processing schemes to optimize the information content. Proposed architectural and data processing schemes could be applicable to either atmospheric or condensed phase environments.

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37. INTERMETALLIC ALLOYS FOR STRUCTURAL USE

Thermal efficiencies of energy conversion systems and heat engines increase with increasing operating temperatures. At present, many advanced engines and energy systems have to operate at reduced temperatures and efficiencies because of strength or corrosion limitations. The materials programs of the Department of Energy are interested in the development of advanced structural alloys that not only increase the thermal efficiency but also provide energy savings through increased component life and improved system reliability. Ordered intermetallic alloys based on aluminides and silicides constitute a new class of metallic materials that have unique properties for structural applications at elevated temperatures in hostile environments. Their attractive properties include good high-temperature strength, resistance to oxidation and corrosion, relatively low material density, and high melting point. Most intermetallic alloys, however, exhibit brittle fracture and low tensile ductility at ambient temperatures, and their use as engineering materials is restricted in many cases by their poor fracture resistance and limited fabricability. In addition, a number of intermetallics are sensitive to moisture and hydrogen in the environment at ambient temperatures. Innovative approaches are thus needed to solve these technical issues in aluminides and silicides, including novel materials processing (such as near-net-shape processing), microstructural control, and alloy design and property improvement through the use of physical metallurgical principles. **Grant applications are sought only in the following subtopics:**

a. Alloy Design of Nickel and Iron Aluminides—Several nickel and iron aluminide alloys have been developed recently for structural uses at elevated temperatures and hostile environments. These alloys possess improved ductility and toughness at ambient temperatures and superior tensile strength at elevated temperatures. The mechanical and metallurgical properties of these aluminide alloys can be further improved by alloy design efforts. Grant applications are sought to: (1) reduce environmental embrittlement in iron aluminides at ambient temperatures (moisture- and hydrogen-induced embrittlements have been alleviated but not completely eliminated in current Fe_3Al and FeAl alloys); (2) improve creep properties of Ni_3Al or iron aluminide alloys (by inhibiting grain-boundary sliding in nickel aluminide alloys and reducing diffusion in iron aluminide alloys); (3) develop wrought nickel aluminide alloys with adequate hot fabricability via control of minor alloying

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additions (<1 atomic percent); (4) improve impact resistance of iron aluminide alloys (these alloys possess only limited impact resistance at ambient and elevated temperatures, even though they have decent tensile elongations in conventional tensile tests); and (5) develop techniques for near-net shape processing, such as reaction synthesis and direct fabrication. For all of the above, emphasis should be placed on innovative material processing to control microstructures and textures, and alloy design and property improvement through the control of minor alloy additions.

b. Cr-based Laves-Phase Intermetallic Alloys or Structural Applications—Laves phases represent an abundant class of intermetallic alloys with possible high-temperature structural applications. Laves phases form at or near the A_2B composition, and there are over 360 binary Laves phases. Cr-based Laves-phase alloys containing refractory elements (such as Cr_2Nb and Cr_2Ta) have unique properties (high melting point, excellent high-temperature strength and creep resistance, and decent oxidation resistance) that make them attractive for high-temperature structural applications. Despite these useful properties, the tendency for low-temperature brittleness has limited the potential use of these alloys. Grant applications are sought to develop new alloys with improved fracture resistance by promoting deformation twinning through the control of crystal structure, adding ductile second-phase particles to bridge cracks, refining grain structure, and controlling grain-boundary chemistry. Little is known about the effect of alloying additions on the mechanical and metallurgical properties of these Laves-phase intermetallics.

Grant applications are also sought to develop two-phase intermetallic alloys based on Cr-Cr_2X (X= Ta, Nb). Single-phase Cr_2X intermetallics are generally very hard and brittle at ambient temperatures. The binary Cr-X phase diagrams indicate the existence of stable two-phase fields based on the soft Cr-rich solid solution and the hard Cr_2X phase. This indicates the possibility of developing strong, tough and oxidation-resistant two-phase alloys through the control of microstructural features, interfacial structure, and alloy additions.

c. Development of Mo_5Si_3-Based Intermetallic Alloys—Mo_5Si_3 is the intermetallic compound with the highest melting point (2180°C) in the Mo-Si binary system. Recent studies indicate that the oxidation resistance of the silicide can be dramatically improved by alloying with a couple of weight percent of boron. The boron additions promote the formation of glassy borosilicate scales that protect the base metal from excessive oxidation at elevated temperatures. The excellent oxidation resistance in combination with superior creep resistance at elevated temperatures makes B-doped Mo_5Si_3 alloys promising for structural applications at temperatures above 1200°C. The major obstacle that keeps the silicide alloys, including both Mo_5Si_3 and Mo_5SiB_2, outside the realm of engineering materials is their poor fracture toughness at ambient temperatures. Grant applications are sought to improve the fracture toughness of these alloys through improved preparation and synthesis techniques, microstructural control, and/or alloy design.

With regard to preparation, brittle B-doped Mo_5Si_3 alloys are difficult to fabricate, and their mechanical properties are sensitive to trace impurities such as oxygen. Grant applications must seek to understand the intrinsic mechanical properties, the silicide alloys must be prepared with high purity, and sizes must be large enough for mechanical and physical property characterization.

With regard to microstructure, the metallurgical factors that control fracture toughness at ambient and elevated temperatures are not well understood. Grant applications must identify the scientific and technological basis for promoting deformation modes and enhancing the fracture toughness of multi-phase alloys based on Mo silicides.

With regard to alloy design, the alloying of B-doped Mo_5Si_3 with different elements needs to be explored through both fundamental calculations and alloying experiments. Grant applications must determine the effectiveness of alloying elements in the silicide alloys and their effect on the thermophysical and mechanical properties at temperatures to 1500°C. The alloying approach must result in significantly improved high-temperature creep resistance, room-temperature fracture resistance, and oxidative stability of the silicide alloys at elevated temperatures.

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* See Section 7.1

38. IMPROVED PERMANENT MAGNETS AND PROCESSING TECHNOLOGIES

Permanent magnet usage is ubiquitous in modern technologies. They are used in electrical motors in household and industrial appliances, in electrical devices that add weight to motor vehicles and airplanes, and in advanced applications such as insertion devices in synchrotron light sources. Improved permanent magnets would lead to higher energy efficiency, to lighter weight devices that require less fossil fuel to transport, or to higher manufacturing tolerances that would allow complex magnet assemblies to be readily configured and maintained. **Grant applications are sought only in the following subtopics:**

a. NdFeB Magnets with Improved Microstructures—Since its discovery in 1983 NdFeB has emerged as a commercial permanent magnet of choice. However, NdFeB still has not reached its theoretical performance limit. Grant applications are sought to develop innovative ways to significantly improve the maximum energy product of NdFeB-based magnets for commercial production and applications. Areas of interest include but not limited to tailored microstructures and high-field cooling.

b. Nanocomposite Permanent Magnets—Nanotechnology now offers the possibility to combine magnetically hard and soft materials on nanoscales in order to realize higher energy products than are presently available commercially. Grant

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applications are sought to develop permanent magnets, based on these nanocomposites, with significantly improved energy products. In addition, grant applications must address the cost effective production of the magnets for commercial application.

c. High-Temperature and/or Radiation Resistant Permanent Magnets—Permanent magnets that can withstand elevated temperatures and/or that are radiation resistant are needed for advanced applications. Sm-Co based magnets have been a commercial material of choice in this regard. Grant applications are sought to significantly enhance the high-temperature and/or radiation hardness properties of permanent magnets based on Sm-Co materials. Grant applications based on new materials or approaches are also of interest, provided that commercial feasibility can be demonstrated. Of particular interest are permanent magnets that have application to energy efficient devices or that can be used as insertion devices for free-electron laser applications.

d. Uniform Permanent Magnets Manufactured for Free-Electron Laser Applications—Permanent magnets with uniform properties and tolerances over macroscopic dimensions are needed for fourth-generation x-ray sources. Presently, in the assembly of free-electron laser insertion devices, magnet blocks are individually measured and matched to reduce field errors and enhance the coherence of the source. The development of homogeneous permanent magnet material would facilitate significantly higher tolerances in the field and vector alignment of the magnet components and thereby simplify the assembly. Therefore, grant applications are sought to develop uniform permanent magnets, for free-electron laser applications, with significantly improved field and vector alignment properties. Grant applications must also address the cost effective manufacturing of the magnets for commercial production.

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39. NEUTRON AND ELECTRON BEAM INSTRUMENTATION

The Department of Energy supports a number of large-scale, national user facilities that provide intense beams of neutrons and electrons for the characterization of materials. **Grant applications are sought only in the following subtopics:**

a. Neutron Facilities—As a unique and increasingly utilized research tool, neutrons have made invaluable contributions to the physical, chemical, and biological sciences. The Department is committed to enhancing the operation and instrumentation of its present and future neutron science facilities so that their full potential is realized.

Grant applications are sought to develop improved neutron detectors and associated electronics needed for DOE's existing and proposed steady-state and pulsed neutron scattering facilities (References 1-2, 5). New detectors must represent substantial improvements in one or more of the following parameters: efficiency at short wavelengths, high counting rate capability, high spatial resolution in one or two dimensions, cost per unit area, or adaptability to unique geometries. Detectors for pulsed neutron applications must be able to identify the time of arrival of each neutron. All detectors must have low intrinsic dark count rates and low sensitivity to gamma radiation.

Grant applications are also sought to develop novel or improved neutron optical components for use in neutron

scattering instruments (References 2-3, 5). Such components include, but are not limited to, neutron choppers, neutron guides, neutron lenses and focusing mirrors, neutron monochromators, or neutron polarization devices including ^{3}He polarizing filters. Applications are also sought for novel use of such components in neutron scattering instruments.

b. Electron Beam Microcharacterization Facilities—The Department of Energy supports four national user facilities for electron beam microcharacterization of materials. These tools are important in the materials and biological sciences and are used in numerous research projects funded by the Department. Innovative instrumentation developments offer the promise of radically improving the capabilities of electron beam microcharacterization and thereby stimulate new innovations in materials science.

Grant applications are sought to develop electron sources for scanning transmission electron microscopy with brightness on the order 10^9 Amp/cm^2/steradian or higher. Current sources are based on tungsten emitters, and it is hoped that higher brightness can be achieved with new materials and designs. Proposed electron sources must be suitably robust for practical applications, have long lifetimes (greater than 6 months), and offer a significant increase in brightness over existing sources.

Grant applications are also sought for technologies that significantly improve the sensitivity or spectral resolution of x-ray detectors for elemental analysis in electron microscopes.

Grant applications are also sought for improved electron detectors suitable for 100-400kV electrons. Grant applications must focus on (1) serial detectors for scanning and/or (2) parallel imaging devices for conventional or scanning transmission electron microscopy. At least one of the following three aspects must be addressed: high quantum efficiency, high spatial resolution, and high temporal resolution. Proposed detectors must be robust and not susceptible to electron beam damage.

Lastly, grant applications are sought to develop stages and holders for transmission electron microscopy, which can precisely control specimen temperature (to an accuracy of 10°C in the range 5-2000K), ambient gas pressure and flow rate (to within several percent for each), and alignment (to an angle accuracy 0.05 degrees).

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40. LITHIUM-BASED BATTERY TECHNOLOGY FOR ELECTRIC AND HYBRID VEHICLES

The commercial use of electric and hybrid vehicle technologies has been limited by the performance and excessive costs of power sources and storage devices. The Department of Energy Advanced Automotive Technologies program is interested in identifying and developing innovative concepts for advanced batteries which will improve the performance, extend the life, and significantly reduce the cost of the vehicles. Grant applications must show how proposed innovations would result in significant advances in performance and cost reduction over state-of-the-art technologies. **Grant applications are sought only in the following subtopics:**

a. Novel Electrochemical Couples for Advanced Batteries—New electrochemical couples offer the potential to overcome the limitations of current electrochemical systems, and to provide high-specific energy, long-life and low-cost alternatives. Therefore, grant applications are sought for new electrochemical couples that offer low cost materials (<$10/kg) capable of high performance (>200 Wh/kg and >400W/kg), long life (>1000 cycles and 10 years), and tolerance to abuse (benign response to standard abuse tests). Proposed approaches could involve new electrode or electrolyte materials; no limitation is placed on the alternatives that could be considered as long as the cost, performance, life, and tolerance-to-abuse goals are met. Evaluation of the technology with regard to the above criteria should be performed in accordance with applicable USABC Test Procedures or Society of Automotive Engineers Recommended Practices (see references that follow). In addition, the new couples should be incorporated into an electrically rechargeable cell technology (at least 0.2 Ampere-hour in size) in order to demonstrate their capability. Lastly, the chemicals used must not be harmful to the environment and must be completely recyclable.

b. Alternative, Low-Cost, High-Performance Anodes for Lithium-Ion Batteries—Lithium-ion batteries use some form of carbon as the active anode material; this material accepts lithium on charge and releases it on discharge at a potential only slightly offset from that of metallic lithium. Unfortunately, many of the carbon forms that have been used suffer from one or more limitations: coke-based systems have limited capacity; natural graphite is subject to structural degradation during cycling, especially if the electrolyte contains propylene carbonate (PC); highly processed materials such as MCMB's (meso carbon micro beads) give reasonable performance but are relatively expensive. Grant applications are sought to develop and demonstrate an anode material that can be produced with a cost similar to that of natural graphite, has the capacity and rate capability of MCMB's, and is tolerant of a PC-containing electrolyte. The Phase I effort should develop (by synthesis or processing) appropriate candidate materials, demonstrate their performance in small cells, address the desired characteristics of low cost and high performance, and provide a strong basis for Phase II. Phase II would demonstrate the production and performance of the new materials in significant quantities (10-100 kg batches) and larger cells (1-10 Ampere-hour). In addition, chemicals used must be compatible with current systems, must not be harmful to the environment, and must be completely recyclable.

c. Alternative, Low-Cost, High-Performance Cathodes for Lithium-Ion Batteries—Lithium-ion batteries use some form of lithiated metal oxide as the active cathode material; this material accepts lithium on discharge and releases it on charge at a potential of 3 to 4 volts against metallic lithium. Unfortunately, many of these materials suffer from one or more limitations: some materials have limited capacity; some (such as some manganese species) cycle poorly and lose capacity or power capability quickly; some (such as materials containing cobalt) are relatively expensive, and some (such as nickel materials) raise questions about safety when abused. Grant applications are sought to develop and demonstrate a cathode material that can be produced with a cost similar to that of manganese spinel and has the capacity, rate capability, and cycle life of the lithiated nickel/cobalt oxides now being used in many production cells. The Phase I effort should develop (by synthesis or processing) appropriate candidate materials, demonstrate their performance in small cells, address the desired characteristics of low cost and high performance, and provide a strong basis for a Phase II. Phase II would demonstrate the production and performance of the new materials in significant quantities (10-100 kg batches) and larger cells (1-10 Ampere-hour). In addition, chemicals used must be compatible with current systems, must not be harmful to the environment, and must be completely recyclable.

d. Alternative, Low-Cost Separators for Lithium-Based Rechargeable Batteries—There is also a need for low cost, alternative separators for lithium-based rechargeable batteries, especially separators that would reduce the cost of materials. Grant applications are sought for separators that can be inexpensively manufactured and easily substituted into current battery systems. The cost of the separators

should be estimated on a $/m^2 basis, and the key performance measure for the separator should be the specific conductivity when used in a standard lithium-ion (Li-ion) system. Performance, when used in a Li-ion cell, must be at least comparable to existing Li-ion technology in terms of power density, expected life, etc. in the temperature ranges to which current systems are exposed. In addition, chemicals used must be compatible with current systems, must not be harmful to the environment, and must be completely recyclable.

e. Alternative, Low-Cost Salts for Lithium-Ion, Rechargeable Batteries—As technology for rechargeable lithium-ion (Li-ion) systems advance, so does the need for lower cost components. A major contributor to the expense of Li-ion based cells is the high cost of producing conductive electrolytic salts. Grant applications are sought for salts that can be inexpensively manufactured and easily substituted into current battery systems. The cost of the salts should be estimated on a $/g-mole basis, and the performance characteristics should be evaluated in terms of the specific conductivity of electrolytes prepared from the salt when combined with standard Li-ion cell solvents. Ultimately, when the salt is used in a Li-ion cell, the performance must be at least comparable to existing Li-ion technology in terms of power density, expected life, etc., in the temperature ranges to which current systems are exposed. In addition, chemicals used must be compatible with current systems, must not be harmful to the environment, and must be completely recyclable.

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** Available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096. Telephone: 724-776-4841. Web site: http://www.sae.org

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41. FUEL PROCESSING & CONVERSION: CATALYTIC CARBONACEOUS FEEDSTOCK GASIFICATION

Once a carbonaceous feedstock has been gasified, and the resulting synthesis gas cleaned of all impurities, it can be used to generate power and produce high-quality liquid transportation fuels and chemicals. This syngas, composed of CO and H_2, is usually produced from reformed natural gas, which yields the high H_2/CO ratios required for downstream processes (e.g., the Fischer-Tropsch technology that converts syngas to high wax concentrations, which are easily cracked to clean hydrocarbon fuels). If the syngas could be economically derived from coal or other more readily available feedstocks (e.g., coal, biomass, wastes, and oil residuals), U.S. dependence on imported oil could be eased. However, traditional gasification processes not only have been the largest cost element in conversion of coal to synfuels (accounting for approximately 50 percent of the cost), but also they have yielded lower H_2/CO ratios. Therefore, improvements in the gasification of coal or other carbonaceous feedstocks offer the largest return on research efforts.

In the past, commercial coal gasification processes have used non-catalytic reactions to produce syngas. In the most common approach, coal is reacted with oxygen and steam to produce a mixture of carbon monoxide, hydrogen, methane, and products of combustion. The reaction of carbon with steam is highly endothermic and consequently extremely energy intensive. The heat requirement is provided by oxidizing part of the coal, which often amounts to one third of the energy in the coal. Operation at lower temperatures is therefore desirable.

Catalytic carbonaceous gasification offers the possibility of carbon-to-syngas conversion, not only at lower temperatures but also at higher H_2/CO ratios. The catalytic gasification of the carbonaceous feedstock(s) could be followed by conventional concentration of pure hydrogen, conversion of H_2-rich synthesis gas to other products, or the generation of electricity in fuel cells, with overall efficiencies approaching 60 percent.

Grant applications are sought only in the following subtopics:

a. Mixed Catalysts for Steam Gasification of Carbonaceous Feedstocks—New catalysts are the key to the development of next generation carbonaceous conversion processes. Advantages include increased rates of gasification at lower operating temperatures, reduced operating pressures, reduced residence times for reactions, reduced sizes of equipment, and better integration with downstream processes. In the past, interest in catalytic gasification has included a whole gamut of catalysts and catalyst systems. However, these single catalyst systems have not been able to overcome difficulties associated with the separation of catalyst and reactant for recycling, or with severe catalyst deactivation due to the presence of minerals in the feedstock or carbonaceous products. Recently, binary, ternary, mixed, and perovskite-type oxide supported catalysts have addressed some of the limitations of single catalyst gasification. Grant applications are sought to develop mixed catalysts for the gasification of coal, either as the sole carbonaceous feedstock or with mixtures containing other carbonaceous feedstocks (biomass, wastes, and oil residuals). Proposed catalysts must be active not only for gasification but also for the reforming of such by-products as methane, aromatics, and tars. Catalysts should resist deactivation by SO_2 and minerals, maintain mobility of the active species at reaction temperatures from 500 to 1000°C, and facilitate replacement or recycle by internal zone regeneration, removal based on particle size, or use of a catalyst support.

c. Fluidized Bed Conversion of Carbonaceous Feedstock and Catalyst for Continuous Gasification—Recent research reports indicate that the use of an Internally Circulating Fluidized Bed (ICFB) reactor can improve catalytic coal gasification processes through improved heat transfer and the ability to separate the combustion and gasification steps in a single vessel. Therefore, grant applications are sought to develop an ICFB catalytic, carbonaceous gasification process (for coal, biomass, wastes, and/or oil residuals) for producing a high H_2/CO product. Grant applications must include accurate reactor modeling (using hydrodynamics, heat and mass transfer, as well as reaction kinetics) in order to predict reactor performance. Applications should focus on novel ways to improve thermodynamic efficiency as well as on catalyst activation, mobility, separation, and regeneration. Particular interest should be given to multiple zone or reactor configurations. It should be noted that catalytic gasification can only be applied to moving-bed or fluidized-bed gasification at temperatures lower than 1000°C.

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PROGRAM AREA OVERVIEW - FOSSIL ENERGY

http://www.fe.doe.gov

Our nation's economic prosperity is built on a secure energy supply. Fossil energy plays a key role with contributions mainly from coal, natural gas, and oil energy resources. However, national complacency, derived from low cost imported oil, has allowed petroleum imports to increase to alarming levels in the last two decades. We need not go far back in history to find out how uncertainty in petroleum supply can affect our nation's economic growth. Nonetheless, our near term power generation and transportation needs still require the utilization of these hydrocarbon-based fuels. As the economy expands, demand for hydrocarbons will increase accordingly. Therefore, the Office of Fossil Energy seeks to develop advanced fossil energy technologies that are environmentally sound and economically competitive.

Technological innovation is required to take advantage of the United States' large supply of coal and natural gas reserves. Coal's major drawback is that it contains sulfur, nitrogen, and trace heavy metals, precursors of pollutants that could have a deleterious effect on the environment. This is particularly alarming because more than half of the electric power generated in the U. S. originates from coal utilization. Natural gas is also produced with a wide variety of pollutant-forming compounds, which preclude some applications such as fuel cells and advanced gas turbines. For both coal and natural gas, further improvements are needed to develop advanced, low cost, high-efficiency processes for the production of clean energy and specialty fuels and chemicals. Advanced technology development in materials utilization, characterization, and recovery will be needed for these products, as well as innovations in sensors, electronics and controls, to be commercially competitive.

Improvements are also needed in our ability to recover both oil and natural gas. About two-thirds of our national petroleum reserve is "unrecoverable"; i.e., it cannot be extracted economically by conventional means. This unused resource could play a major role in supplementing the national petroleum supply if efficient approaches were developed for improved extraction. Natural gas production and utilization could also be increased through improved characterization of gas reservoirs.

The purpose of this solicitation is to seek the participation of small businesses in addressing problems related to the utilization of coal and natural gas to produce power, fuels, or chemicals, and to the recovery of oil and natural gas.

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42. ADVANCED POWER SYSTEMS AND CONTROL DEVICES

The efficient and environmentally safe utilization of our most abundant fossil energy resources, coal and natural gas, is needed to sustain economic progress. The Department of Energy (DOE) is supporting the development of advanced technology power plants that offer higher efficiency, lower emissions, and reduced capital and operating cost. The "Vision 21" concept is a new approach to the production of energy from fossil fuels in the 21st century. It will integrate advanced concepts for high-efficiency power generation and pollution control into a class of fuel-flexible facilities capable of co-producing electric power, process heat, and high value fuels with near zero emissions. The approach includes a variety of configurations to meet differing market needs, including both distributed and central generation of power. The DOE is interested in innovative research related to coal and biomass gasification, fuel cells, and high pressure fluidized bed combustion systems that will benefit these advanced technologies and the Vision 21 concept. **Grant applications are sought only in the following subtopics:**

a. Co-Feeding of Biomass with Coal for Gasification in Power Generation—Most entrained gasification systems, currently being developed for power production, process coal with water to make a coal-water slurry, which is fed into a gasifier. The gasifier operates at high temperatures and pressures (about 400 psi) to produce a fuel gas, which is then burned in a turbine to make electric power. As the disposition of biological waste has become an increasing environmental concern, a recurring idea has been to gasify biomass in place of some of the coal. This co-feeding would offer cost savings from not having to dispose of the biomass waste, reduced environmental pollution associated with the waste, and a relatively cheap source of energy. However, disadvantages include unreliability in the quantity and quality of the biomass feedstock, the potential need for different feed systems for different forms of biomass, and industry reluctance to use biomass. One approach to reduce industry reluctance is to reduce the percent of biomass in the co-feed so that a new feed system is not required. Therefore, grant applications are sought to develop a system to gasify biomass with coal, without requiring the creation of a new feed system. The most appealing biomass feedstocks would have high BTU content, would have consistent composition characteristics, are not currently being made into an economically viable product, and have current disposal methods that are expensive and/or cause environmental concerns. Sewage sludge, sawdust, and municipal waste are already under investigation; therefore, preference will be given to grant applications for other biomass materials. By the completion of the Phase II project, the proposed system must be evaluated in terms of feeding performance, gasifier performance, and the economics of the power plant that would use the co-feed slurry.

Proposed systems must be tested with biomass-coal slurries with at least four different coals, depending on the origin of the biomass. If the biomass is available in only the East or the West, use only eastern or western coals, respectively. If the biomass is available in both the East and West, use two eastern and two western coals. Each of the four coals should be tested separately as a coal/biomass slurry, with varying biomass percentages, up to at least 20 percent biomass. For each coal/biomass combination, the following parameters must be determined: solids loading, viscosity, and heating value.

b. Power Electronics for Solid-Oxide Fuel Cells—Fuel cells offer a distinct advantage over power conversion technologies that use conventional fossil fuels due to the inherently high efficiencies associated with their direct conversion of electrochemical energy to useful work without the intermediate production of heat. Accordingly, the National Energy Technology Laboratory's Solid State Energy Conversion Alliance (SECA) program is attempting to develop low-cost, broadly applicable, 5 kW solid-oxide fuel cell (SOFC) systems to encourage commercialization of this important technology. However, cost-effective, compatible power electronics remains an issue in fuel cell system commercialization. Therefore, grant applications are sought to improve the cost, compatibility, and performance of fuel cell power electronics in the range of 5kW. Areas of research interest include the development of: (1) board or chip modules that maintain compatibility between fuel cell electronics and power electronics while being amenable to mass production manufacturing techniques; (2) thermally resistant power electronic components that would help alleviate the need to insulate or cool the components (note that SOFCs currently operate between 800°C and 1000°C); and (3) cost-effective switching algorithms to reduce electrical loss during DC to AC conversion while minimizing complexity. Grant applications may focus on power electronic requirements for single or multiple applications such as stationary, transportation, or military.

c. Mercury Control—There have been numerous debates on the need for mercury control in the utility industry, and the Environmental Protection Agency has delayed any determination on regulation till December 2000. In the

meantime, several mercury control systems are under investigation. Wet flue gas desulfurization systems, designed for sulfur dioxide, are being investigated for the removal of not only oxidized mercury but also non-soluble elemental mercury. Novel regenerable techniques have been investigated for both forms of mercury. Perhaps the most investigated technology has been the use of fine particulates of activated carbon (AC), injected upstream of particulate control devices that are already in place. After adsorbing the mercury, the AC is collected by the particulate control device along with fly ash and other particles of combustion. The activated carbon approach has shown promise at pilot-scale, with 30 to 90 percent mercury removal, depending on such factors as speciation of the mercury, temperature, vapor-phase flue gas conditions/constituents, particle size of the AC, and the dynamics of the particulate control device (i.e., whether it is an electrostatic precipitator or a fabric filter). However, in order to achieve satisfactory mercury removal, the AC approach requires carbon-to-mercury mass ratios as high as 100,000-to-1, with estimated costs for the utility industry in the range of $2 to 5 billion per year (or more, for nominal mercury removals of 80 percent using powdered AC). In addition, the collection of AC with the fly ash increases the concentration of carbon in the fly ash, leading to an estimated 20 percent loss from current fly ash sales.

Grant applications are sought to develop alternative adsorbents (i.e., not using activated carbon alone) for the capture of elemental and oxidized mercury from the combustion of coal, in the flue gas upstream of the particle control devices (i.e., electrostatic precipitators (ESPs) and fabric filters) utilized in the coal-fired utility industry. The novel adsorbents must be capable of capturing both forms of mercury at temperatures between 230° and 320° Fahrenheit, within 0.5 to 1.5 seconds (typical residence times upstream of existing utility ESPs), at a cost that does not exceed 25 cents per pound of adsorbent, and with mercury capture efficiencies between 60 and 90 percent. (The mercury capture efficiency may apply to the two forms of mercury individually or to total mercury, and does not include the natural capture of mercury by the fly ash.) In addition, the captured mercury species must be in a stable form, so that there would be no re-emission or escape of the mercury to the environment if the absorbent were disposed in a landfill or used with fly ash or other by-products. Also, there should be no adverse impact on the performance of products and processes associated with mixtures of the absorbent and by-product (e.g., fly ash or the pozzolon process for concrete).

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43. FUELS TECHNOLOGIES AND MATERIALS FOR FUEL APPLICATIONS

The development and widespread use of advanced fuels is driven by concerns about protecting the environment (by decreasing emissions) and increasing energy security (by

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converting a broad base of primary resources to a set of common fuels of high quality). For example, coal and other carbonaceous materials can be converted to synthesis gas by gasification. This gas mixture then becomes a common starting point for the synthesis of a variety of clean fuels that can be used by new transportation power plants in an environmentally friendly way. Two examples of such fuels are hydrogen and methanol. Hydrogen used in fuel cells is a key component in the concept of low or zero emission vehicles. Methanol can be used directly as a fuel, used with a reformer to generate hydrogen, or used as an intermediate to produce other clean burning oxygenated fuels. However, the full exploitation of these fuels requires the development of certain technologies. For the generation and use of hydrogen, the development of advanced carbon materials can potentially improve several aspects of the production and storage processes. To improve the economics of methanol synthesis, measurement and control technology is needed to combat the effect of synthesis gas poisons on the methanol synthesis catalysts. **Grant applications are sought only in the following subtopics:**

a. Advanced Carbon Materials—Advanced carbon materials will play an increasingly important role in the production and use of advanced fossil fuels and energy related technologies in the future. These materials have potential application in gas separation, in water and air purification, as fillers and conductive additives to plastics, and as catalyst supports, molecular sieves, hydrogen selective membranes, and high-storage-capacity materials. Components derived from carbon-based materials can be molded into intricate shapes, thus avoiding the cost of machining. In addition, the use of these lightweight, strong materials as structural members could increase energy efficiency in the transportation sector. Unfortunately, many of these new carbon forms, especially nanotubes, fibers, and related nanoparticles, are currently produced in small quantity and at considerable expense. Before their full potential can be realized in commercial applications in the energy sector, the cost of production must be brought down. Therefore, grant applications are sought for novel, innovative concepts and processes for the production of any the aforementioned carbon materials in such a way as to allow their penetration into the current market. Examples might include synthesis processes using flames, arcs, microwave discharge, pyrolytic reactions over catalysts, or other methods leading to the production of nanoscale materials with graphene-like molecular structures. Proposed processes will be judged on cost, amenability to scale-up, and selectivity to the desired product (so that the synthesis will not be encumbered by an excessive need for purification steps). Also, the product must consistently meet high standards of quality; therefore, a clear set of quality control parameters must be defined. Phase I results must include an estimate of process economics.

b. Control of Potential Catalyst Poisons in Coal-Derived Synthesis Gas —Gasification technologies used to convert coal and other environmentally disadvantaged carbonaceous feedstocks into synthesis gas feed streams produce a variety of bulk gas compositions, which can contain a myriad of trace components. Additionally, the transient composition of the gases produced during upsets or routine process changes may have an impact on the downstream synthesis process that is not foreseen in standard designs. Although, the stable, long-term operation of downstream reactors requires synthesis gas of the most exacting purity, the catalysts used in the conversion of synthesis gas to methanol, other liquid fuels, and chemicals have been found to be sensitive to the low levels of poisons that are sometimes found in synthesis gas produced by commercial-scale gasifiers. In the specific case of methanol synthesis in a liquid phase reactor, trace components (such as hydrogen sulfide, carbonyl sulfide, iron carbonyl, nickel carbonyl, and arsenic) with concentrations as low as the parts-per-billion level can quickly and irreversibly deactivate the fine catalyst particles suspended in the slurry. Grant applications are sought to develop: (1) new on-line and laboratory methods to measure and characterize the presence of trace contaminants at the parts-per-billion level, (2) trace contaminant cleanup or reduction systems, and (3) new, multi-functional adsorbent materials that can be used in catalyst guard bed systems to protect down stream reactors.

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44. MATERIALS RESEARCH FOR FOSSIL ENERGY APPLICATIONS

The objective of the Fossil Energy Materials Program is to conduct research and development on materials for longer-term fossil energy applications as well as for generic needs of various fossil fuel technologies. The focus is on research leading to a scientific understanding of high-performance materials compatible with hostile fossil environments. The aim of exploratory research is to generate new materials, ideas and concepts which have the potential to significantly improve the performance or cost of existing fossil systems or enable the development of new systems and capabilities. Consequently, developing improved materials for high-temperature, high-pressure heat exchangers, high-temperature fuel cells, and advanced turbine systems constitute major objectives of the program. **Grant applications are sought only in the following subtopics:**

a. Heat Exchanger Materials for Coal-Fired Power Systems—The need for higher efficiencies, lower emissions, and lower costs for coal-fired power generation systems based on Rankine cycles will require higher steam temperatures. For example, to achieve 50 percent efficiency, steam temperatures of 700°C will be required, which corresponds to surface temperatures on the boiler finishing superheaters on the order of 750°C. This is considerably higher than the operating temperatures of the ferritic steels (i.e., FeCr, with 9-12% Cr) that are currently under development. On the other hand, advanced austenitic steels have adequate strength at these higher temperatures; however, they have inadequate resistance corrosion from the coal ash that is generated in the process. Therefore, grant applications are sought for improved alloys or coatings for high temperature components in these coal-fired power systems. Proposed approaches must provide adequate creep strength and corrosion resistance without compromises on cost, welding ability, or fabrication ability.

As an alternative to steam boiler Rankine cycles, indirectly-fired gas turbines can achieve high efficiencies while still using coal as the fuel. In these systems, air is heated to 760°C in a metallic heat exchanger, followed by further heating to 980°C in a natural-gas-fired ceramic heat exchanger. Grant applications are sought for ceramic heat exchanger materials that can withstand the high temperatures in indirectly fired cycles. Proposed approaches must include predictions of stress distribution, especially around joints or

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points of contact, as well as predictions of the resistance to thermal cycling. Grant applications must also address issues related to fabrication/processing, mechanical properties, corrosion, nondestructive evaluation, and fracture mechanics.

b. Materials for Intermediate Temperature Solid Oxide Fuel Cells—The solid-oxide fuel cell (SOFC) offers significant advantages in the conversion of fossil fuels to electrical power. Because there is no intermediate heat production step, SOFC efficiencies can be much higher than current methods of producing power. Current SOFC configurations require high-temperature operation to maintain a sufficiently low area-specific resistance while ensuring long-term reliability. The only material set that has been successfully demonstrated over a substantial period of time uses yttria stabilized zirconia as the electrolyte, nickel/zirconia cermet as the anode, and lanthanum strontium manganite as the cathode. This combination has a lower temperature limit of about 800°C, and possibly 750°C with some modifications. However, high- temperature operation is costly due to the higher energy requirements, radiation losses, and material sintering problems. Therefore, grant applications are sought to identify and characterize combinations of SOFC electrolyte, anode, and cathode materials that can operate in the 500°C to 800°C range. Materials must be selected so that (1) the cost of materials does not exceed the cost of the above-mentioned, currently-used material set; and (2) the resultant structure, using the proposed set of materials, is amenable to cost effective manufacture. Electrolyte transference numbers must be determined, and shown to be adequate in a typical SOFC environment, in Phase I before proceeding to characterize the full materials set(s). The characterization must demonstrate that the resultant structure can meet SOFC requirements, namely a power density of 0.3W/cm^2 at 0.7 V, corrected for test cell resistance, in the indicated temperature range and subject to typical fuel and oxidant environments. The characterization must also address the chemical stability between the components as well as lifetime effects (phase stability, thermal expansion compatibility, conductivity aging, and electrode sintering). Lastly, the characterization must be as complete as possible and avoid duplicating previously developed information.

c. Smart Materials for Life Prediction of Advanced Gas Turbines—The Next-Generation Gas Turbine Research Program has the goal of developing and commercializing ultra-high efficient, environmentally superior, cost competitive gas turbine systems (30 MW or greater output rating) for base-load applications in both the utility and independent power markets. In order to maximize the useful life of the coatings and base materials of expensive hot-gas-path (HGP) components in these systems, non-destructive evaluation methods are needed to assess degradation, as an alternative to destructive sectioning and metallographical analysis. In addition, thermal sensing systems will also be needed for these HGP components because their useful life is strongly dependent on the actual temperatures experienced during operation. Therefore, grant applications are sought to develop "smart materials" that can be used to non-invasively determine important life-cycle properties (such as residual stresses, the state of damage, and temperature) while operating in the harsh turbine environment. The information provided by the smart material could then be used via suitable process control to assess remaining life or to regulate operating conditions.

The generic term "smart materials" includes materials or probes that can provide information on a material or coating while in service. For example, piezo-spectroscopic methods can determine the stress level in a thermally grown protective oxide (TGO) on a turbine blade by utilizing shifts in Cr luminescence peaks, a technique that can be used even when the TGO is covered by a thermal barrier coating (TBC). In turn, the stress state can be related to pre-spalling events in the TBC. As another example, surfaces coated with thermographic phosphors (i.e., ceramic materials doped with rare-earth elements) can be used for non-contact surface temperature measurements of turbine engine components. When the surface is irradiated with the appropriate excitation UV wavelength, the rare earth fluorescence decay and emission-line intensity both decrease with increasing temperature.

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45. OIL AND GAS TECHNOLOGIES

The Department of Energy (DOE) seeks innovative methods and concepts that will contribute to more efficient and economic processes for the recovery and utilization of oil and natural gas. Much of the known reserves of oil and gas discovered in the United States can not be recovered by conventional techniques. Ultimately, the utilization of fossil fuels can be enhanced by the commercial production of pure fuels from natural gas. Accordingly, characterization, production, and utilization are important to the success of the program. **Grant applications are sought only in the following subtopics:**

a. Advanced Oil Well Stimulation—Oil well formation damage, begun during well drilling and continued through stimulation and the rest of an oil well's life, is detrimental to both oil production rate and ultimate recovery. Grant applications are sought to develop innovative methods and chemicals to stimulate oil wells in the least damaging manner possible. Stimulation techniques for both new and old wells are of interest, and the stimulation techniques must be compatible with the formations that are exposed to them. The future commercialization potential of the proposed technology will be a consideration in the grant award selection process. Grant applications involving microbial, seismic, and well heating or heat treating techniques are not of interest and will be declined.

b. Natural Gas Downstream Processing and Utilization—Over the past decade, the DOE Gas Processing Program has evolved in support of our national goal to expand the development and utilization of our abundant domestic natural gas resources. The use of natural gas offers environmental benefits over other conventional energy sources and helps to offset increasing oil imports. However, some natural gas resources (e.g., low on-shore or off-shore wells, coalbed methane production or landfill gas sites) contain large amounts of nonmethane gases and natural gas liquids that make them uneconomical to market as natural gas. If the nonmethane impurities and natural gas liquids could be removed, the economic and energy impacts would be significant. Grant applications are sought to develop small scale facilities for raising or upgrading low-quality raw natural gas to pipeline quality by removing nitrogen, carbon dioxide, water, hydrogen sulfide, and natural gas liquids. With respect to the removal of hydrogen sulfide, the proposed approach must account for its subsequent or direct conversion to elemental sulfur or other environmentally benign products. Grant applications are limited to approaches that have crosscutting applications in coal and other fuel related areas where feed, combustion, or waste streams require the removal of impurities or the need to concentrate specific components. These approaches membranes, absorption/adsorption, or a hybrid combination of these technologies. In addition, in order to show market potential, teaming with industry for possible field testing and demonstration of these techniques is required.

c. Stripper Gas Well Technologies—The production of natural gas from so-called stripper wells (wells that produce less than 60,000 cubic feet of gas per day) is hampered by the productin of water with the natural gas and by low gas pressures in the formation (i.e., pressures lower than or approximately equal to the pipeline pressure at the surface). Methods exist for separating water from natural gas and for overcoming the low gas pressure (i.e., by producing the gas against low pressure and then compressing it to pipeline pressure). However, due to the sensitive economics of these low-producing, limited-reserve stripper wells, present water removal and compression methods are not economic (i.e., too expensive for most applications). Therefore, grant

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applications are sought to develop low cost, innovative water remediation technologies (i.e., separation, clean-up for disposal) and compression technologies that can increase natural gas production or reduce operations costs of stripper gas wells.

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