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Closing Date: January 6, 2004

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U.S. Department of Energy
SBIR/STTR Program
SC-32/Germantown Building
1000 Independence Avenue, S.W.
Washington, DC 20585-1290

READ CAREFULLY
Major Changes and Helpful Tips

- Grant applicants are required to provide a Dun and Bradstreet Data Universal Numbering System (DUNS) number on the grant application cover page. Individuals who would personally receive a grant from the Federal Government apart from any business are exempt from this requirement. To obtain a number at no cost, call toll-free 1-866-705-5711.

- The budget for the DOE STTR Program has increased from $5 Million to $10 Million in FY 2004. Therefore, we expect to make about 28 Phase I awards in STTR.

- The Reporting Requirements have changed. Pay close attention to Section 5.2.

- Building Security will not let you or any courier on the DOE premises. If you plan to deliver your application in person or through a courier, the individual must stop at the security checkpoint and identify yourself and have security call 301-903-1414 for package pickup.

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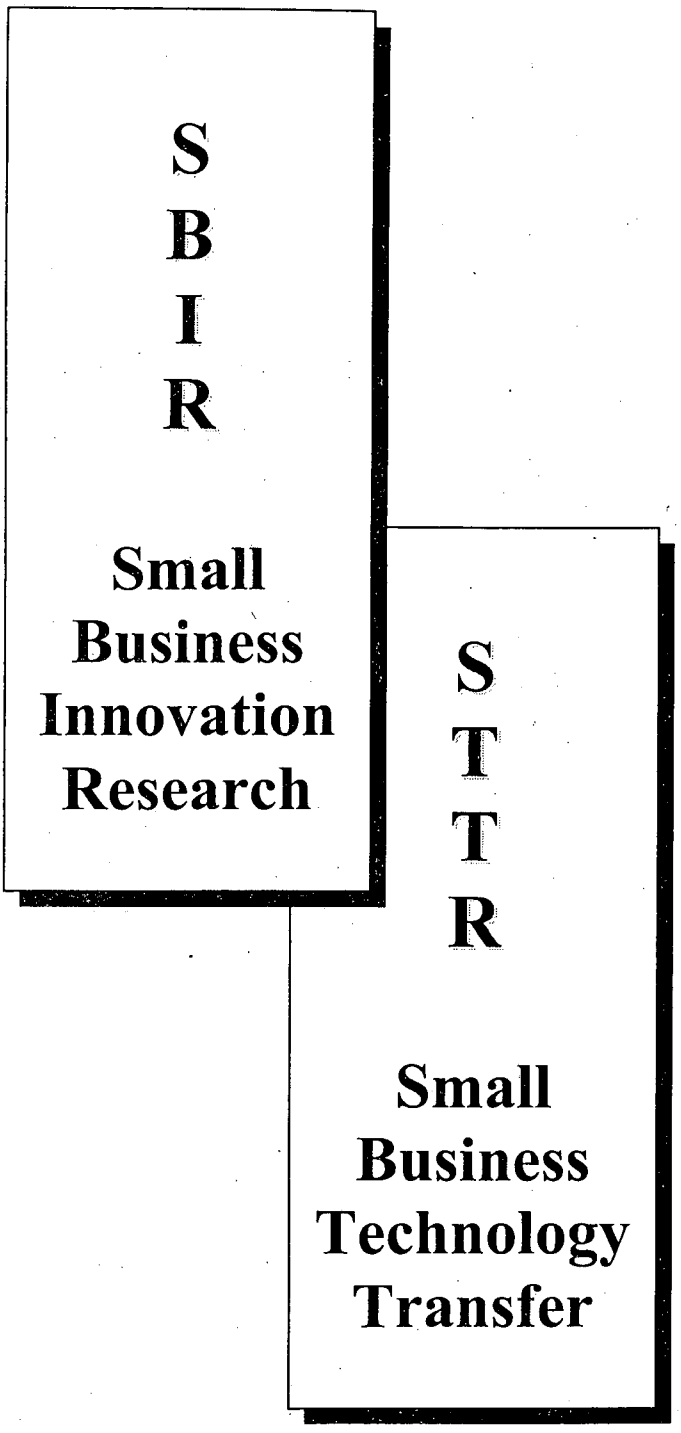

Technical Topic Descriptions

PROGRAM AREA OVERVIEW
FUSION ENERGY SCIENCES

http://www.ofes.science.doe.gov

The Department of Energy sponsors 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 fusion energy concepts not based specifically on the use of plasmas for producing energy/electricity for non-defense purposes will be declined.

1. FUSION SCIENCE AND TECHNOLOGY

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; and for innovative approaches to fusion. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector. A list of items under the heading "Goods and Services that are needed by the Fusion laboratories" can be found in the Office of Fusion Energy Sciences Website (**URL: WWW.OFES.SCIENCE.DOE.GOV**). Grant applications are sought only in the following subtopics:

a. Diagnostics for Magnetic and Inertial Fusion Plasma Research—Grant applications are sought to develop: (1) 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; (2) new diagnostics for measurements in three-dimensional plasmas characteristic of stellarators, as well as diagnostics that are especially adapted to other innovative experiments; (3) diagnostic methods for examining the edge and divertor regions in Tokamak plasmas and for understanding electron thermal transport (e.g., high-k fluctuation diagnostics, core magnetic fluctuation diagnostics, and profile diagnostics on smaller devices); (4) diagnostics applicable to the management of particle and energy inventory, to profile control and thermal barrier formation, and to burning plasmas including ITER; and (5) diagnostics for the visualization of turbulence in two and three dimensions, and the imaging of non-thermal electrons in two dimensions. 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) are of interest. Measurements must be both spatially and

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

temporarily resolved for both the absolute values of parameters and for small relative differences. Real-time measurements of the pertinent parameters will be required for providing feedback and plasma control. Further information on experiments on innovative fusion concepts is available at the OFES website.

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 modelling these plasmas.

Grant applications are also sought to develop instrumentation and time-resolved measurement techniques of high-charge-density, heavy-ion beams of energy greater than 0.5 MeV and radius ~1 to 5 cm. Beam parameters of interest include current, density distribution, beam position, energy, energy distribution, emittance, and space potential, in the Injector, Transport, and Final Focus sections. Of particular interest are innovative non-intercepting position detectors and optical (including scintillator-based) beam diagnostics suitable for rapid characterization of beams in both the present (0.5 to 2 MeV) and higher energy ranges, and diagnostics for characterizing trapped secondary electron distributions. Further information may be obtained in the HIF Symposia series (see reference for 12th International Symposium).

b. Components for Heating and Fueling of Fusion Plasmas and Tokamak Facility Operations—Tools are needed to support fusion experimental research in such areas as plasma heating and the control of temperature profile, plasma density, and plasma density profile. Grant applications are sought to develop: (1) components related to the generation, transmission, and launching of high power electromagnetic waves in the frequency ranges of ion cyclotron resonance heating (50 to 300 MHz), lower hybrid resonance heating (2 to 20 GHz), and electron cyclotron resonance heating (100 to 300 GHz); (2) concepts that would generate energetic neutral beams; (3) computer codes for maintainability/reliability assurance technologies and plant operation simulation codes applicable to fusion experiments; and (4) artificial intelligence techniques to monitor Tokamak plant operation and real-time or impending fault conditions. Areas of interest include: components such as power supplies, fault protection devices, antenna and launching systems, tuning and matching systems, unidirectional couplers, circulators, mode convertors, windows, output couplers, and loads; diagnostics to evaluate the performance of these components; and energy extraction systems for spent electron beams and particle accelerators.

c. Plasma Simulation 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. Unfortunately, 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.

d. Components for Innovative Approaches to Fusion—Innovative confinement concepts is a broad-based, long-range, fusion research activity that specifically addresses parameters that could lead to attractive and practical use of fusion power. This research includes investigations in stellarators, spherical torus, reversed field pinches, field reversed

configurations (FRC), spheromaks, magnetized target fusion, levitated dipole, flow-stabilized (long-pulse) z-pinch, rotationally stabilized magnetic mirror, inertial electrostatic confinement, and magneto-Bernoulli confinement. Grant applications are sought for scientific and/or engineering developments in support of any aspect of these research activities. In particular, plasma accelerators, capable of launching 0.1 mg to 1 mg of plasma/plasmoid to velocities in excess of 200 km/s with a timing precision better than a microsecond down to nanoseconds and with a controllable density profile of high uniformity and purity are sought. Further information on experiments on innovative fusion concepts is available at the OFES website.

Lastly, grant applications are sought to develop innovative, high-economic-value, non-electric applications that could be considered as spin-offs from fusion research, including but not limited to the production of medical isotopes, industrial applications, nuclear instrumentation, explosives detection, processing of hazardous materials, and space applications.

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***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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Subtopic d: Components for Innovative Approaches to Fusion

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2. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies 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 achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. A list of items under the heading "Goods and Services that are needed by the Fusion laboratories" can be found in the Office of Fusion Energy Sciences Website (**URL: http://www.ofes.science.doe.gov**). **Grant applications are sought only in the following subtopics:**

a. Structural Materials and Coatings—Grant applications are sought for research that will enable the development of advanced reduced activation materials and electrically insulating coatings. Materials systems of interest are limited to the following: (1) vanadium alloys, (2) oxide dispersion strengthened (ODS) ferritic steels, (3) high-toughness tungsten alloys, (4) SiC/SiC composite or graphite-fiber/SiC-matrix structural composites, and (5) electrically insulating coatings on vanadium to reduce magnetohydrodynamic (MHD) effects in liquid lithium cooled systems. For vanadium alloys, areas of interest include the development of improved multiphase alloys, increased oxidation resistance, and decreased sensitivity to bulk ductility degradation associated with gaseous impurity pickup. For ODS ferritic steels, areas of interest include developing low cost production techniques, improved isotropy of mechanical properties, joining methods, and the development of improved steels with the capability of operating up to ~800°C while maintaining adequate fracture toughness at room temperature and above. For tungsten alloys, areas of interest include improvements in the grain boundary strength, fracture toughness, and joining techniques. For SiC/SiC composites, the primary areas of interest are the development of radiation resistant hermetic coatings and the development of advanced joining processes; techniques to improve thermal conductivity are of secondary interest. For electrically insulating coatings, the reduction of MHD effects are of primary interest; but grant applications also must account for compatibility with both the coated vanadium alloy and a liquid lithium coolant for long time operation at 400-700°C, the use of candidate coatings on actual system components, and the long term reliability and/or *in situ* repair of defects that could develop in the coating.

Grant applications are also sought to develop: (1) innovative new modeling tools ranging from atomistic and molecular dynamics simulations of atomic collision and defect migration events (including solute binding

effects) to improved finite element analysis (mechanical deformation and fracture) or thermodynamic stability (materials by design) tools; and (2) innovative methods or experimental apparatuses that would enhance the ability to obtain key mechanical or physical property data on miniaturized specimens – of particular interest is the micromechanics evaluation of deformation and fracture processes.

In this subtopic, the emphasis is on materials for structural applications; grant applications for issues related to plasma-surface interactions will not be considered. Also, grant applications related to general fabrication techniques and the economics of SiC composite component fabrication (e.g., low cost production methods) are not of interest.

b. Particle and Heat Removal with Liquid Surfaces—Innovative liquid surface concepts are desired for heat removal from surface heat fluxes at first walls and divertors of about 2 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 liquids with direct exposure to the plasma that can potentially remove particles as well as surface heat. Candidate liquid metals include lithium, tin-lithium, tin, gallium, and lead-lithium. Other candidate liquids are lithium bearing salts, such as BeF_2-LiF and BeF_2-LiF-NaF. Grant applications are sought to develop: (1) techniques for the removal of first wall and divertor heat loads 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, such as the addition of alloying materials, to improve the compatibility of candidate liquids with either the plasma operation (e.g. lowering vapor pressure) or with structural/insulator materials (e.g. ceramic insulators that can be wetted by Li); (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; (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); (6) efficient techniques for pumping liquid metals in the presence of a magnetic field, including the production of free surface flows; and (7) techniques for validation of fluid flow and heat transfer models.

c. 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 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 out gassing under irradiation).

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3. INERTIAL FUSION ENERGY

Inertial fusion energy is produced by ignition and burn of an energy-producing target. Conditions necessary for ignition and burn result from the external application of

energy to the fuel target by an external driver. Although several drivers such as lasers and ion beams have been considered, the emphasis in the fusion energy science program is on intense heavy ion beams as drivers. These beams are produced by induction linear accelerators with components to produce, accelerate, transport, and focus beams of required energy and intensity. The Fusion Energy Sciences program in inertial fusion energy supports research and technology in the generation, transport, and measurement of these heavy ion beams. There is also interest in selected technology topics with relevance to different inertial fusion energy driver concepts. A list of items under the heading "Goods and Services that are needed by the Fusion laboratories" can be found in the Office of Fusion Energy Sciences Website (**URL: WWW.OFES.SCIENCE.DOE.GOV**). **Grant applications are sought only in the following subtopics:**

a. Beam Generation and Transport—Grant applications are sought for the development of high current, high brightness ion sources for heavy ion induction linacs that can produce beam currents >0.5 A with <1 π mm-mrad emittance and short pulse lengths ~ 1 μsec, and that can be extended to compact arrays of multiple beams. Grant applications are also sought for prototypes of multiple beam arrays of superconducting quadrupoles for multiple beam transport, the array cryostat, and cryogenic leads in a compact design that is compatible with induction acceleration modules. The focusing unit of interest consists of a doublet of quadrupole arrays in a common cryostat, with typical parameters as follows: number of channels, 4-12; lattice length, 45 cm; clear bore diameter, 50-70 mm; central field gradient above 100 T/m; and magnetic length, ~10cm. Careful consideration of the termination of the magnetic fields at the periphery of the array is required to ensure adequate field quality.

b. Models for Electron Production in Accelerators for Heavy-Ion Beam-Driven Fusion—Grant applications are sought for computational modules to calculate (1) cross-sections for the production of neutrals, ions, and electrons via wall bombardment by beam ions and other species, (2) source distribution functions for the resultant products, (3) cross sections for ionization and charge-exchange of the neutrals by the ion beam, and (4) the volumetric evolution of neutral gas. Grant applications are also sought for the development of a set of subroutines suitable for straightforward inclusion into existing intense-beam simulation codes (such as WARP, BEST, and/or LSP). Initial calculations using these models should be carried out in a regime relevant to the upcoming high current experiments at Lawrence Berkeley National Laboratory (LBNL). The models should be sufficiently general that they can be applied to a wide variety of ion accelerators for a broad range of applications.

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. Innovative materials, which can withstand this environment, are sought. Schemes that can protect or shield the first wall are also of interest. In addition, innovative low-cost approaches for testing pulsed damage resistance of chamber materials are needed.

(2) Numerical models for simulating the behavior of target debris in chambers following energy release. This includes interactions of high-energy (MeV) particles with the surrounding gas/plasma mixture, high-temperature plasma dynamics and radiation processes, and effects of external magnetic fields on the transport of target debris through the chamber.

(3) 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.

(4) 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

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targets must be prepared and injected each day at a rate of 5-10 Hz into a target chamber operating at elevated emperatures. These targets must be precisely made and cost less than $0.30 each.

(5) 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) are also needed.

(6) Design, construction, testing, and 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).

(7) Crystal growth of Yb-doped Sr5 (PO4)3F, or Yb:S-FAP crystals. Laser-quality crystals of dimensions 4 x 6 x 0.8 cm^3 are needed for installation into the candidate IFE driver based on diode-pumped solid state lasers. All crystal growth methods will be considered including Czochralski and the Heat Exchanger Method (HEM). Currently, each method entails synthesis of the melt from the following starting materials: SrHPO4, SrCO3, SrF2 and Yb2O3. However, other synthesis methods also are of interest. Large, high-quality crystals should be obtained by starting with a seed, and, under appropriate conditions, pulling the crystal from the melt as in the Czochralski method or directionally solidifying the melt in the case of the HEM. Seven specific defects must be managed: cloudiness in as-grown crystals, an anomalous Yb-related absorption, low-angle grain boundaries, bubble core, cracking, second phase inclusions that form around the outside of Czochralski grown crystals, and color centers in HEM crystals. Colorless, high quality, crystals with an Yb-doping level greater than or equal to1.5 x 10^{19} ions/cm^3 in the resulting crystal are required for laser development. In addition, the residual stress in crystals must be low enough so that slabs can be fabricated without cracking.

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PROGRAM AREA OVERVIEW
HIGH ENERGY PHYSICS

http://doe-hep.hep.net/home.html

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 following 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 nuclear force, and gravity. For example, in the past we have learned that the electromagnetic and weak forces are two components of a single force, called the electro-weak force. This unification of forces is analogous to the unification in the mid-nineteenth century of electric and magnetic forces into 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 advance its scientific knowledge and technological capabilities, to advance its industrial competitiveness, and possibly to discover new and innovative approaches to its energy future.

Experimental research in HEP is largely 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 has a significant role in the Large Hadron Collider project under construction 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 five decades in our understanding of particle physics, future progress depends to a great degree 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.

4. 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 research in high-field superconductor and 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. Grant applications that propose the use of third party resources (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 and related processing techniques for high critical-current, high critical-field conductors for the production of low alternating current (AC) loss conductors used in

very high-field magnets. Grant applications for the improvement of starting raw materials are of particular interest. 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. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K. Applications must demonstrate such property improvements as higher critical-current densities and higher critical fields, as well as the manageable degradation of these properties as a function of applied strain. Advanced conductor fabrication techniques of interest include methods to utilize high aspect ratio stranded conductors or tape geometries in particle accelerator applications. Any proposed process improvements must result in equivalent performance at reduced cost. 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. Grant applications that address the development of A-15 and oxide superconductors must physically deliver a sufficient amount of material for winding and testing in small dipole or quadrupole magnets.

Because 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 with properties optimized at the higher field portion of the short sample curve. These grant applications must focus on conductors that will be acceptable for accelerator magnets.

Lastly, 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) 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; (4) designs for bent (e.g., bending radius in the range 0.75 to 1.25m) solenoids (e.g., 2 T, 30 cm inside diameter) with superimposed dipole fields (e.g., 1 T) for dispersion generation in large emittance beams.; (5) improved industrial fabrication methods for magnets such as welding and forming; or (6) improved cryostat and cryogenic techniques.

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5. 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 high energy physics research. Relevance to applications in high energy physics must be explicitly described in the submitted grant applications. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 15. 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. 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. For all proposed concepts, stageability, beam stability, manufacturability, and high wall plug-to-beam power efficiency should be considered. Grant applications must address the marketability of any systems, technologies, and devices to be developed.

b. Novel Device and Instrumentation Development—Grant applications are 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 0.7 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.

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 that provide substantial improvements over currently available lasers in one or more of the following parameters: longer wavelengths (2 to 2.5 micrometers for use with Si transmissive optics), very short wavelengths (< 200 nanometers) with low mode numbers (M-squared < 100) and high pulse energy (> 0.1 J) for photo-ionized plasma sources, higher power, higher repetition rates, or shorter pulse widths.

Grant applications are sought to develop high density (range of 1018-1020 cm-3), high repetition rate (10 Hz) pulsed gas jets, capable of producing fan-shaped gas plumes with long lengths on the centimeter scale and narrow widths of a few hundred microns. These gas jets are to be used in laser wakefield accelerators. The gas plumes should have sharp edge gradients, on the order of 100 microns. The gas jet system should have the flexibility to offer longitudinal density profile control using, for example, multi-nozzle systems produced, potentially, with Micro-Electro-Mechanical Systems technology. Ideally, the pulse duration of the jets should be less than 1 ms to minimize the amount of gas loading in vacuum chambers.

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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 – yet with comparable or greater peak currents and significantly higher repetition rates – for bunches from a matrix cathode. In addition, grant applications are sought to develop a bright DC/RF photocathode electron source that combines a pulsed high electric field DC gun and a high field rf accelerator, operates at a repetition rate of several kHz, and has electron bunch specifications that are similar to those listed above.

Grant applications are also 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.

Finally, grant applications are sought for research and development on electron sources to be used as polarized beam injectors for linear accelerators, including linear colliders. These sources should be gated 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 greater than or on the order 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 and Systems—Grant applications are solicited for developing new or improved computational tools specifically for the design, study, or operation 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 simulation packages for injectors or photoinjectors. Specific examples include: (1) improved space-charge algorithms; (2) improved algorithms for computing self-consistently the effects of wakefields and coherent synchrotron radiation on the detailed beam dynamics; (3) improved fully 3-D algorithms for the modeling of transversely asymmetric beams; and (4) explicit end-to-end simulations that provide for more accurate beam-quality calculations in full injector systems.

Lastly, grant applications are sought to improve (1) software systems for command and control functions, real time database management, real-time or off-line modeling of the accelerator system and beam,and status display systems encountered in state-of-the-art approaches to accelerator control and optimization; and (2) decision and database management tools, specifically for use in planning and controlling the integrated cost, schedule, and resources in large high energy physics R&D and construction projects.

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6. 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 research 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 15. 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 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. For use in muon accelerator R&D, achieving gradients of 5-10 MeV/m for cavities with frequencies between 20 and 200 MHz is also of interest. Means for achieving unloaded voltage gradients >40 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 frequencies from 1.2 to 40 GHz or between 20 and 300 MHz for muon accelerators.

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 (>75 MW at 11 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. Of particular interest are innovations related to cost saving, manufacturability, and electrical efficiency. For example:

(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 way is through the use of sheet beam klystrons. Accordingly, grant applications are sought for these rf sources or their components such as single or dual sheet beam gridded or diode guns, sheet beam klystron rf structures, or whole single channel or dual channel sheet beam klystrons. Engineers at SLAC's Klystron Department are available to assure that designs match various linear collider rf system concepts. In general, these designs must be directed toward the economical construction of a klystron capable of delivering 75-120 MW of X-band (11.424 GHz) power, in a pulse length of 600 nsec – 3.2 microseconds, to accelerator loads. Two classes of klystrons are envisioned for development: first, a cathode pulsed dual sheet beam klystron delivering 120 MW of peak power, 3.2 microseconds, 120 PPS into an rf pulse compression system that combines multiple klystron power, segmented in time to drive multiple accelerator sections; and second, a grid pulsed single or dual sheet beam klystron, 75-120 MW of peak

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power, 600 nsec, 120 PPS that directly drives a single accelerating structure – such a gridded, short-pulse klystron may provide an alternative to a pulse compression system for a linear collider.

(3) An advanced crossed-field amplifier or magnetron for X-band linacs may be capable of operation at lower voltage and higher peak current than klystrons, which require low perveance to be efficient. Although the long-range development goal is 50-100 MW, grant applications are sought for the initial development of an amplifier targeted at 5-10 MW, possibly with permanent magnet focusing. Additional information can be provided by Sami Tantawi at SLAC (e-mail: tantawi@SLAC.Stanford.edu; phone 650-926-4454; fax: 650-926-5368).

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 - 40 GHz), and pulse lengths of several microseconds. Therefore, grant applications also are sought for passive and active rf components such as over-moded mode converters from rectangular to circular waveguide and vice versa, high-power rf windows, circulators, isolators, switches, quasi-optical components, and high-power rf pulse compression methods for use in future linear colliders.

Lastly, grant applications are sought for the initial design, modeling, and development of a compact multi beam klystron (MBK) at 201.25 MHz to support proton drift tube linacs. The source must produce 5 MW pulsed RF at 201.25 MHz for 500 microseconds at 15 Hz rate. For application at Fermilab, this power source, together with its low and high level systems, must fit into a footprint of 12 feet by 24 feet with a ceiling height of 12 feet. Output power must be supplied via a 9-inch coaxial hard line that can be pressurized to 12 psig. Also, because the MBK would be part of phase and amplitude feedback loops, it must operate linearly 15 % below saturation. Efficiency of about 50 percent and gain of 50 dB are required. Tube lifetime of about 30,000 hrs is very desirable.

c. **New Concepts or Components for Pulsed Power Modulators and Energy Storage**—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 200 - 800 A, with pulse lengths of 0.2 – 4.0 microseconds, and rise- and fall-times of less than 0.5 microsecond. Innovation related to cost saving, 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. Of particular interest is the development of cathode modulators for driving single or double sheet beam diode gun klystrons, based on the Marx multiplier principle. This design should produce 400-500 kV, 3.2 microsecond pulses; have rise and fall times less than 600 nsec; and be compact and cost competitive compared to present cathode pulse modulator schemes.

Grant applications are also sought to develop improved high power solid-state switches for pulse power switching. For some applications, requirements will 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. These switches must handle very high di/dt (20 kAmps/microsecond) at low duty cycle (<0.1 percent).

Existing IGBT (Insulated Gate Bipolar Transistor) packages for high voltage (> 3.3kV) and high pulsed current (> 3 kAmps peak, 59 Amps average) are not optimized for very high speed pulsed power applications (6.6 MW peak for 3.2 microseconds at 120 Hz) due to failure modes induced by very rapid fall time (di/dt >10 kAmps/microsecond) and/or rise time (dV/dt >15 kV/microsecond) upon device turn-off. Therefore, grant applications are sought to reduce these failure modes through improved packaging of commercial IGBT chips, by incorporating appropriate protective circuitry in a high voltage power package designed specifically for high-speed transients. Additional information can be provided by Richard Cassel or Saul Gold at SLAC (Cassel: e-mail: rlc@SLAC.Stanford.edu; phone: 650-926-2299; fax: 650-926-3588; Gold: e-mail: slg@SLAC.Stanford.edu: 650-926-4450; fax: 650-926-3654).

Lastly, grant applications are sought to develop and optimize high reliability, high energy density energy storage capacitors for future 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/microsecond), and (3) be packaged to meet the requirements of high power solid state board layouts and have minimum production cost.

Further information regarding the last two paragraphs can be obtained from either Ron Koontz or Saul Gold at SLAC (Koontz: e-mail: rfkap@SLAC.Stanford.edu; phone: 650-926-2528; fax: 650-926-3654; Gold: e-mail: slg@SLAC.Stanford.edu; phone: 650-926-4450; fax: 650-926-3654).

Note: See Topic 7 regarding the solicitation of grant applications for components and systems that target the presently envisioned X-band Linear Collider.

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 (from 2 millisecond pulses at 20 MHz to 0.1 millisecond pulses at 200 MHz). Higher power (>100 MW) pulsed sources at higher frequencies (from 30 microseconds at 400 MHz to 10 microseconds at 800 MHz) are also of interest. All muon collider amplifiers must have moderate repetition rate capability (e.g., 15 Hz). Another important factor is the cost per unit of peak power, including the cost of required power supplies.

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* Available from Springer-Verlag New York, Inc. Telephone: 800-777-4643. Website: http://www.springer-ny.com

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. Grant applications that propose the use of third party resources (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. 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) 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.

(2) High Voltage Pulse Transformers with low leakage inductance and minimized core loss, for use in solid-state-switch driven modulators. The modulators will drive a pair of X-band klystrons at 120 Hz with ~500 kV, 520 A peak and 3 microseconds pulse-length. A preferred design would use a segmented core, a fractional-turn primary with about 12 sections, and a multi-turn basket-type secondary of about 11 turns.

Additional information can be obtained from Ray Larsen at SLAC (e-mail: 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 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 "first cut" (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. For these applications, mechanical tolerances of 50-100 micrometers must be achieved. Of particular interest are grant applications that seek to develop or advance processes for precision machining subsequent to net shaping, with dimensional and flatness tolerances of one micrometer and surface finishes of 10 nanometer (rms). Other areas of interest include (but are not limited to): powdered metallurgy with copper plating; precision mechanical measurement device(s) for RF component fabrication; development of microwave Quality Control techniques for X-band cell manufacturing, able to resolve shifts of 0.5 MHz in cell resonant frequency due to multidimensional errors; and surface treatments for

RF components and assemblies. Lastly, manufacturing processes for the mass production of ultra-high vacuum, high-power parts made from stainless steel, aluminum, or copper alloys are also of interest, provided that tolerances and applicability are similar to those listed above. All grant applications must demonstrate significant cost reduction over conventional techniques (such as current numerically controlled machining methods). Additional information can be provided by Gregg Kobliska or Harry Carter at Fermilab (Kobliska: e-mail: gregg@fnal.gov; phone: 630-840-4893; fax: 630-840-nnnn; Carter: e-mail: hfcarter@fnal.gov phone: 630-840-2458; fax: 630-840-8022).

Finally, 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 8]; or (4) new permanent magnet focusing structures with reduced cost or improved reliability for X- or S band klystrons or for X-band crossed-field amplifiers. Further information can be obtained from Sami Tantawi at SLAC (e-mail: tantawi@SLAC.Stanford.edu; phone 650-926-4454; fax: 650-926-5368).

c. Positron Target Station Systems Analysis—The high radiation environment and power dissipation requirements of the positron production target in a linear collider will force system designers to understand the design choices and trade-offs involving the targeting configuration, redundancy, operational availability, maintainability, performance, and life cycle cost. For example, should targets be swapped annually or be run until failure? Should repairs be made on demand or preemptively, when the system is hot or after a protracted cool-down period? What level of sophistication in remote handling techniques is appropriate? How do such choices affect the system configuration? Grant applications are sought for a systems analysis study, which raises different options and evaluates tradeoffs, to guide system designers in making design choices. Engineers in the NLC Positron Source R&D group at SLAC are available to work with applicants in understanding the performance considerations and past studies of failure modes and effects. For more information, contact John Sheppard at SLAC (e-mail: jcs@slac.stanford.edu, phone: 650-926-3498, fax: 650-926-5124).

d. Focusing and Auxiliary Systems—As a potentially more economical and reliable alternative to DC electromagnets, permanent magnets are under consideration. Grant applications are sought to develop engineering design and evaluation techniques applicable to permanent magnets used in linear colliders, and for a highly reliable permanent magnet quadrupole that is remotely tunable over a range of ±20 percent 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. Further information can be obtained from John Cornuelle, SLAC (e-mail: johnc@SLAC.Stanford.EDU; phone: 650-926-2545; fax: 650-926-5124).

The low-level microwave reference signal for a linear collider will be distributed at a sub harmonic of the linac frequency. Therefore, grant applications are sought to develop 6X frequency multipliers with an output frequency of 2856 MHz, unprecedented phase stability of order 100 fs, noise floor of –160 dBc (input referred), and long-term drift not to exceed 100 fs from 20 to 40 degrees C. Additional information, can be provided by Ron Akre at SLAC (e-mail: akre@SLAC.Stanford.EDU, phone: 650-926-4754; fax: 650-926-3654).

Grant applications also are sought to develop one or both of two types of precision translation actuators suitable for integration into hundreds of mover systems (each with several degrees of freedom) for the spatial adjustment of beam line components in the radiation environment of a high-energy linear accelerator that is several miles long. The continuous adjustment of linac components will require more than 10,000 actuators (of Type 1) with load capacity of 250 kg, resolution of 1 micron, range of plus or minus 1 mm, stability of 1 micron per day, maximum speed of 2 mm/min, power of 20 W at full speed, and average unit cost below $200. The final focusing magnets will require tens of even more precise actuators (Type 2) with 1000 kg load capacity, 0.1 micron resolution, plus or minus 0.5 mm range, 0.5 micron per day stability, and 100 W power at full speed. The latter type should be functional at 4 Tesla and 3 degrees Kelvin, and may cost more than the Type 1 actuators. Both types should use less than 2 W when static and should fail safely when power is

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removed. Localized position readout would be desirable as an independent supplement to the precision measurements by beam position monitors. Further information can be obtained from Gordon Bowden at SLAC, (e-mail: gbb@SLAC.Stanford.edu; phone: 650-926-2991; fax: 650-926-5368.)

In addition, grant applications are sought for an optical real-time network for pulsed-accelerator control. This development requires combining timing information with data-communication functions on a single optical fiber connected to pulsed device-controllers. These controllers provide interfaces to systems for such functions as low-level RF signal generation, modulator control, beam position monitors, and machine protection system sensing. A single fiber should provide each controller with an RF-synchronized clock that has an arrival time phase-locked to the temperature-stabilized RF reference phase, a similarly-locked machine pulse fiducial point, digital data for machine pulse-type selection and specific pulse identification, and real-time-streaming pulsed waveform data-acquisition capabilities. The network should provide real-time fast feedback loop closure and TCP/IP connectivity for slow control functions, such as database access, device configuration, and code downloading and debugging.

Finally, proposals are sought for real-time processors and software for pulsed accelerator control and monitoring, based on a multiprocessor architecture that can be deeply embedded within pulsed device-controllers employing system-on-a-chip, field-programmable gate-array or application-specific integrated circuit technologies. These architectures should feature distinct processors for pulse-to-pulse real-time functions and conventional slow control functions. Architectural provisions for supporting machine protection functions via an additional processor or dedicated hardware should also be included. These processor designs for pulsed device controllers and the timing/communications network mentioned in the previous paragraph should be engineered for both resistance to electromagnetic interference generated by nearby, large, pulsed-power systems and maximum availability in remote deployment locations.

Further information on the preceding two paragraphs can be obtained from Ray Larsen at SLAC (e-mail: larsen@SLAC.Stanford.EDU; phone: 650-926-4907; fax: 650-926-5124).

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(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 or accelerator control.

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 - 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 AREA OVERVIEW
ADVANCED SCIENTIFIC COMPUTING RESEARCH

http://www.sc.doe.gov/ascr/mics/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., supercomputers and large experimental facilities with scientists who need access to the data.

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.

10. HIGH PERFORMANCE NETWORKS

The Department of Energy (DOE) supports a wide range of research activities in mathematics, information, and computational sciences to accelerate scientific discoveries. This topic addresses research needs in high-performance networks to support distributed high-end computing, remote instrumentation, and data storage; and large-scale, secure, scientific collaboration. Emerging science experiments sponsored by the DOE are expected to generate several petabytes of data, which will be transferred to geographically distributed terascale computing facilities for analysis and visualization by thousands of scientists. This requirement calls for networks with unprecedented capabilities – networks that, unlike today's commercial networks, can securely deliver multi-Gigabits/sec throughput to high-end scientific applications. Therefore, grant applications must propose advanced network technologies that can operate at 10 Gbps and beyond. Additional information on the DOE networking requirement can be obtained in the network research sections of a DOE network planning workshop report available at: http://doecollaboratory.pnl.gov/meetings/hpnpw/finalreport/.

Grant applications are sought only in the following subtopics:

a. Ultra High-Speed Network Components—The new vision of grid-based scientific computing in the DOE environment calls for network infrastructures with unprecedented capabilities to support its science mission. These networks are envisioned to deliver multi-Gbps (10-100 Gbps) throughputs to distributed applications. The network infrastructures will require advanced network technologies that are radically different from those used in today commercial networks, including the Internet. Grant applications are sought to develop ultra high-speed network components (both hardware and software) that can deliver multi-gigabits/sec throughput to high-end scientific applications. Components of interest include, but are not limited to: (1) cost effective 10 Gbps interfaces for GigE (Gigabit Ethernet) or OC-192 (Optical Carrier level 192), (2) dedicated channel sharing and scheduling, (3) Transmission Control Protocol (TCP) extensions for ultra high-speed data transfers, (4) scalable non-TCP transport protocols, OS-bypass for wide-area networks, and (5) ultra high-speed network security systems that include firewalls and intrusion detection systems.

b. Traffic Engineering for Ultra High-Speed Network—Grant applications are also sought to develop scalable efficient techniques for modeling and controlling complex traffic processes in ultra high-speed networks dominated by a few very large traffic flows. For this purpose, grant applications must focus on the development of scalable tools, techniques, and services for traffic engineering in ultra high-speed networks (10 – 40 Gbps end-to-end). Areas of interest include, but are not limited to: (1) scalable end-to-end network measurement and analysis tools and services, (2) innovative tools and services for predicting network performance and controlling large traffic flows, (3) advanced tools for modeling complex traffic patterns in packet-switched and agile lambda-switched networks, and (4) advanced simulation tools and techniques for very high-speed networks. Scalability issues associated with proposed approaches must be addressed by demonstrating how the resulting system will be operated at 10 GigE and OC-192.

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

SCALABLE MIDDLEWARE AND GRID TECHNOLOGIES

vances in high performance network capabilities and laboration technologies are making it easier for large ›graphically dispersed teams to collaborate ectively. This is especially important for research teams that use major computational resources, data resources, and experimental facilities supported by DOE. The importance of collaboratories is expected to increase in the future. However, significant research questions must be addressed if collaboratories are to achieve their potential, namely, by providing: (1) remote access to facilities that produce petabytes/year; (2) remote users with an experience that approaches "being there;" (3) remote visualization of terabyte to petabyte data sets from computational simulation; and (4) effective remote access to advanced scientific computers. Research and software tool development are needed to support coordinated and dynamic resource sharing in areas such as resource discovery, resource access, authentication, authorization, accounting, etc., in the areas listed below. Any tools or services developed should be interoperable according to emerging standards from the Global Grid Forum. **Grant applications are sought only in the following subtopics:**

a. Scalable Middleware Technologies—Grant applications are sought to develop scalable middleware technologies that will: (1) enable universal, ubiquitous, easy access to remote computing resources and scientific instruments; (2) facilitate collaboration among distributed science teams; and (3) enable a new generation of distributed high-end applications. Areas of interest include, but are not limited to, secure directory services, scalable authentication/authorization services, deployable LAN and WAN QoS services, wide-area distributed data management, efficient multicast capabilities, automatic resource discovery protocols, remote data access services, and network-attached memory and storage systems.

b. Scalable Grid Technologies—Grant applications are sought to develop scalable grid technologies to support the emerging distributed computing network that provides dependable, consistent, pervasive, scaleable, and efficient access to various resources integrated into a distributed infrastructure that can be accessed wherever and whenever by DOE scientists. These resources include visualization systems, computer systems, data storage and archive systems, and scientific instruments. Areas of interest include, but are not limited to, collaborative visualization systems, collaborative problem solving services, application level fast data transfer toolkits, real-time analysis, group collaboration, co-scheduling of distributed resources, grid accounting and billing mechanisms, data management tools, science portals, on-line instrumentation, and fast data transfer management services.

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12. TECHNOLOGY FOR SOFTWARE LIBRARIES

The Advanced Scientific Computing Research (ASCR) program has been fully or partially responsible for funding the research and development of a wide range of robust high-quality numerical algorithms for scientific computation. These include the development of libraries such as EISPACK, LINPACK, LAPACK, ScaLAPACK, ARPACK, CLAWPACK, PETSc, TAO, CHOMBO, ebCHOMBO, SALSA, MPSALSA, LOCA, HYPRE, SuperLU, FronTier, and many others. However, critical issues still require resolution to ensure that the value of such scientific software is maintained and that the large investment in the research and development of these algorithms is maximized. These issues include enhancing user interfaces, providing distribution support, providing maintenance activities such as collecting and tracking bug reports, fixing bugs, and providing portability across platforms (including porting to new computational architectures). **Grant applications are sought only in the following subtopic:**

a. Deployment and Maintenance of Robust Numerical Software Libraries—Grant applications are sought to: (1) develop new maintenance and distribution mechanisms to ensure that updated scientific libraries are subjected to validation and verification testing; (2) implement formal tracking mechanisms for bug reports, bug fixes, and update notification for a wide range of scientific algorithm libraries; (3) develop and maintain mechanisms for providing cost effective portability of scientific libraries across a wide range of computer architectures, from desktop systems to massively parallel leadership-class supercomputers; (4) develop and maintain high-quality user documentation for each component of scientific software, including advice on domains of applicability for each module; and (5) develop comprehensive email- or web-based user support services for scientific libraries. The ASCR program will assure that successful grant applicants will obtain access to relevant computational facilities, as needed for their research.

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PROGRAM AREA OVERVIEW
NUCLEAR PHYSICS

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

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. 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.

Nuclear physics research is carried out at National accelerator facilities and through university programs. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator at MIT allow detailed studies of how quarks and gluons bind together to make protons and neutrons. CEBAF is planning a future upgrade in which the electron beam energy is doubled from 6 to 12 GeV. The Relativistic Heavy Ion Collider (RHIC), now in operation 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. RHIC is planning a beam luminosity upgrade in the future; a new electron-ion collider is also being discussed. The nuclear physics program supports research and facility operations that are directed towards understanding the properties of nuclei at their limits of stability and of the fundamental properties of nucleons and neutrinos. This research is made possible with the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) and the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL), which provide complementary facilities for stable and radioactive beams as well as a variety of species and energies. In addition, the operations of accelerators for in-house research programs at four universities (Yale University, Washington University, Texas A&M University, and Triangle Universities Nuclear Laboratory (TUNL) at Duke University) provide unique instrumentation with a special emphasis on training of students. The nuclear physics program also supports non-accelerator experiments such as the Sudbury Neutrino Observatory (SNO) facility, constructed by a collaboration of Canadian, English, and U.S. supported scientists, now taking data on solar neutrino fluxes and providing the first results on the "appearance" of oscillations of electron neutrinos into another neutrino type. 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 could 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 technical topics which follow describe research and development opportunities in the equipment, techniques, and facilities that are needed to conduct and advance nuclear physics research at existing and future facilities.

13. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Large scale data storage and processing systems are needed to store, access, retrieve, distribute, 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. The experiments at such facilities are extremely complex and expensive, involving thousands of detectors that produce raw experimental data at rates of up to several hundred MB/sec, resulting in the annual production of data sets on the order of several hundred Terabytes (TB), with Petabytes (PB) of data in the near future. Many 10s of Terabytes of data per year are distributed to many institutions around the U.S. and other countries for analysis by the scientific collaborators. Research on large scale data management systems is required to support these large 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. Large Scale Data Storage—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. Because current technology keeps all disk drives powered and spinning, the infrastructure costs of operating a petabyte disk storage system could be prohibitive. However, one 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, and that scale linearly with the amount of data accessed rather than the total storage capacity.

b. Large Scale Data Processing and Distribution—Some nuclear physics facilities produce 100s of TB of data per year, soon to be PB per year. Many 10s of TB of data per year are distributed world-wide for analysis

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by the scientific collaborators. A recent trend in nuclear physics is to construct these data handling and distribution systems using data grid infrastructure software such as Globus and Condor. In the near future, these systems will use the Open Grid Services Architecture (OGSA), which is based upon Web Services. At that time, it will be necessary for any proposed infrastructure software solutions to integrate well with this new data grid technology. Grant applications are sought for: (1) hardware and/or software techniques to improve the effectiveness and reduce the costs of storing, retrieving, and moving such large data volumes, including, but not limited to, automated data replication coupled with application data catalogs, and distributed storage systems of commercial off-the-shelf (COTS) hardware; (2) hardware and/or software techniques to improve the effectiveness of computational and data grids for nuclear physics (see reference 3 for these uses) – examples include integrating the management of distributed open source Relational Data-Base Management System (RDBMS) with OGSA and developing application level monitoring services for status and error diagnosis; and (3) effective new approaches to data mining, automatic structuring of data and information, and facilitated information retrieval. Applicants that propose data distribution projects are encouraged to contact the U.S. National Nuclear Data Center to determine relevance and possible future migration strategies into existing infrastructures.

c. Large Scale Data Archiving and Maintenance—One of the legacies of experimental nuclear physics experiments is the data produced. Large projects like RHIC, Gammasphere, or the Jefferson Laboratory produce unique data, reflecting measurements that may never be repeated. Experience tells us that only a small portion of the data is subjected to detailed analysis and published. Typical large research projects focus on the experiment and data taking but not on long term data preservation. Therefore, grant applications are sought to develop permanent archiving and user-friendly Internet dissemination procedures for the data from nuclear physics experiments along with associated detector description and calibration information.

d. Cluster Interconnects—Large scale (thousands of CPU's) computing platforms are needed to perform theoretical calculations of Lattice Quantum ChromoDynamics (LQCD), a method of extracting the predictions of the fundamental theory of the interactions of quarks. While these science applications can use virtually any supercomputer architecture efficiently, the computational demands are such that the cost effectiveness of the platform (measured in floating point operations per second per dollar, as sustained by a large scale parallel application) is a significant consideration. Clusters would be an appropriate platform for these calculations because of their low cost per compute node, but only if the cluster interconnects were of high bandwidth, low latency, and low cost. Although current offerings fall short on at least one of these metrics, the science applications are such that nearest-neighbor communications predominate in a three or four dimensional torus; therefore, a fully interconnected switch fabric is not essential – a torus mesh with routing also would be a feasible design. Grant applications are sought to develop mesh-communication-optimized cluster interconnects scalable to thousands of nodes at modest cost. The interconnects must be well coupled to next generation commodity compute nodes (to achieve high bandwidth and low latency on future systems) and must have a cost well below the cost of the compute node.

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14. 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, pulse shape discrimination capability, and background suppression. Of particular interest are innovative readout electronics for use with the nuclear physics detectors described in Topic 16. 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 are needed to replace analog signal processing in nuclear physics applications. Grant applications are sought to develop: (1) digital processors that simplify the analog design, using such features as pile-up rejection and ballistic deficit correction; (2) digital pulse processing electronics for commonly used nuclear physics detectors in general, and for position sensitive solid-state detectors in particular; and (3) fast digital processing electronics that improve the accuracy of the analog electronics, such as in determining the position of interaction points (of particles or photons) to an accuracy smaller than the size of the detector segments.

b. Integrated Circuits—Grant applications are sought for 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, peak sensors, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) multiple sampling ASICs, to allow for pulse shape analysis; (3) readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample-and-hold integrated circuits; and (4) constant fraction discriminators with uniform response for low and high energy gamma-rays. These circuits should be fast; low-cost; high-density; configurable in software for thresholds, gains, etc.; easy to use with commercial auxiliary electronics; low power; compact; and efficiently packaged for multichannel devices.
In addition, planned luminosity upgrades at RHIC and experiments at the Large Hadron Collider will require fine-grained vertex and tracking detectors (both silicon and gas) for high particle multiplicity environments. Therefore, grant applications are sought for advances in microelectronics that are specifically designed for low noise amplification and processing of detector signals, and that are suitable for these next generation detectors. The microelectronics and associated interconnections must be lightweight and have low power dissipation. Designs that minimize higher gate leakage currents due to tunneling and maintain dynamic range would be of particular interest.

c. Advanced Devices and Systems—So called Active Pixel Sensors in CMOS (complementary metal-oxide semiconductor) technology are replacing Charge Coupled Devices as imaging devices and cameras for visible light. Several laboratories are exploring the possibility of using such devices as direct conversion particle detectors. The charge produced by an ionizing particle in the epitaxial layer is collected by diffusion on a sensing electrode in each pixel. The charge is amplified by a relatively simple low noise circuit in each pixel and read out in a matrix arrangement. If successful, this approach would make possible high resolution position sensitive particle detectors with very low mass (only about 100 microns of silicon in a single layer). This approach would be clearly superior to the present technology of hybrid vertex detectors consisting of a separate silicon detector layer bump-bonded to a CMOS readout circuit. Grant applications are sought to attempt this very significant advance in integrated detector-electronics technology, using CMOS monolithic circuits as particle detectors. The new active pixel detector with its integrated electronic readout should be based on a standard CMOS process. The challenge is to design the sensor and low noise readout circuits to have sufficiently high sensitivity and low power dissipation in order to detect the charge signal developed in a thin epitaxial layer (~10 microns), as available in some of the standard CMOS processes.

In addition, grant applications are sought for improved or advanced devices and systems used in conjunction

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with the electronic circuits and systems described in subtopics a and b. Areas of interest regarding devices include radiation-hardened, wide-bandgap semiconductors (i.e., semiconductor materials with bandgaps greater than 2.0 electron volts, including Silicon Carbide (SiC), Gallium Nitride (GaN), and any III-Nitride alloys), inhomogeneous semiconductors such as SiGe, and device processes such as silicon-on-insulator (SOI) or silicon-on-sapphire (SOS). Areas of interest regarding systems include bus systems, data links, event handlers, multiple processors, trigger logics, and fast buffered time and analog digitizers. For detectors that generate extremely high data volumes (e.g., >500Gb/s), advanced high-bandwidth data links are of interest. Lastly, 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 and Advanced Interconnection 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.

Lastly, many next generation detectors will have highly segmented electrode geometries with 5-5000 channels* per square centimeter, covering areas up to several square meters. Conventional packaging and assembly technology cannot be used at these high densities. Grant applications are sought to develop: (1) advanced interconnect technologies that address the issues of high density, area-array connections including modularity, reliability, repair/rework, and electrical parasites; (2) technology for aggregating and transporting the signals (analog and digital) generated by the front-end electronics, and for distributing and conditioning power and common signals (clock, reset, etc.); (3) low-cost methods for efficient cooling of on-detector electronics; and (4) standards for interconnecting ASICs into a single system for a given experiment, where individual circuits may have been developed by diverse groups in different organizations – this would include combining different technologies with different voltage levels and signal types, with the goal of possibly reusing the developed circuits in future experiments.

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* Available from National Technical Information Service (NTIS). Telephone: 1-800-553-6847. Web site: http://www.ntis.gov/ (Please note: Items that appear to be unavailable via the Web site might be obtained by phoning NTIS. See Solicitation General Information and Guidelines, section 7.1.)

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15. 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 advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's superconducting Relativistic Heavy Ion Collider (RHIC) with heavy ion beam energies up to 100 GeV/amu and polarized proton beam energies up to 250 GeV, technologies associated with RHIC luminosity upgrades and the development of an electron-ion collider, superconducting radio frequency (srf) linear accelerators such as the electron machine at the Thomas Jefferson National Accelerator Facility (TJNAF), 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 that 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. Materials and Components for Radio Frequency Devices—Grant applications are sought to improve or advance superconducting and room temperature materials or components for radio frequency (rf) devices used in particle accelerators. Areas of interest include: (1) peripheral components, for both room temperature and superconducting structures, such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, rf power couplers, and magnetostrictive or piezoelectric cavity tuning mechanisms; (2) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (3) methods for manufacturing superconducting radio-frequency (>500 MHz) accelerating structures with $Q_0<10^{10}$ at 2.0 K; (4) improved superconducting materials that have lower RF losses, operate at higher temperatures, and/or have higher RF critical fields than sheet niobium; (5) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment that simplify procedures and reduce costs associated with repair and modification; (6) development of simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 Kelvin; and (7) development of techniques to create a layer of niobium on the interior of a copper elliptical cavity, such as by energetic ion deposition, so that the resulting 800-1500 MHz structures have $Q_0 > 8 \times 10^9$ at 2 K and so that the overall fabrication costs are reduced relative to using sheet niobium.

Grant applications are also sought for the design, computer-modeling, and hardware development of 5 kW and 13 kW cw power sources at 1497 MHz. Examples

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of candidate technologies include (but are not limited to): solid-state devices, multi-cavity klystrons, Inductive-Output Tubes (IOT's) or hybrids of those technologies. The devices should: (1) be capable of operating efficiently over a range of output power levels; (2) include a method for power adjustment other than using the rf drive signal and the voltage of any primary dc source – for example, a klystron should include a gun-current modulating electrode; and (3) have an ac-to-rf conversion efficiency greater than 50%. Interested parties should contact Dr. Leigh Harwood at Jefferson Laboratory [harwood@jlab.org] for further specifications.

Lastly, grant applications are sought for a new generation of high-voltage (up to 200 k VDC) electronic switching devices with peak current capability on the order of 100 A. Such devices should also be capable of operating as very high power (tens of Megawatts), low-frequency (below 100 MHz) rf power amplifiers with suitable external rf circuits. A possible technology is the Hobetron. Interested parties should contact Abbi Zolfaghari (*abbi@bates.mit.edu*) at MIT-Bates Laboratory.

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) continuous wave (cw) structures, both superconducting and non-superconducting, for the acceleration of beams in the velocity regime between 0.001 and 0.01 times the velocity of light and with charge-to-mass ratios between 1/30 and 1/240; (2) superconducting rf accelerating structures appropriate for RIA drivers, for particles with speeds in the range of 0.02-0.8 times the speed of light; (3) innovative techniques for field control of ion acceleration structures (1° of phase and 0.1% amplitude) and electron acceleration structures (0.1° of phase and 0.01% amplitude) in the presence of 10-100 Hz variations of the structures' resonant frequencies (0.1-1.5 GHz); (4) multi-cell, superconducting, 0.5-1.5 GHz accelerating structures that have sufficient higher-order mode damping for use in energy-recovering linac-based devices with ~1 A of electron beam; (5) methods for preserving beam quality by damping beam-break-up effects in the presence of otherwise unacceptably-large higher-order cavity modes – one example of which would be a very high bandwidth feedback system; and (6) methods and/or devices for reducing the emittance of relativistic ion beams – such as electron or optical-stochastic cooling.

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 aspects such as high efficiency, high-charge-state ions, small emittance and energy spread, 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 and devices to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers or special stripping techniques); (5) high brightness electron beam sources utilizing continuous wave (cw) superconducting rf cavities with integral photocathodes operating at high acceleration gradients; (6) ~1 GHz cw polarized electron sources delivering beams of ~10 mA with longitudinal polarization of ~80%; (7) novel high quantum efficiency, long life photocathode materials, such as chalcopyrites, for brightness electron sources with polarizations >90%; (8) devices, systems, and sub-systems for producing high current (>200μA), variable-helicity beams of electrons with polarizations >80%, and which have very small helicity-correlated changes in beam intensity, position, angle, and emittance; (9) 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), and which are compatible with ultra high vacuum environments; (10) wavelength tunable (700 to 850 nm) mode-locked lasers with pulse repetition rate between 0.5 and 3 GHz and average output power >10 W; and (11) a single wavelength 532 nm mode-locked laser with pulse repetition rate 0.5 to 3 GHz and average power ~ 100 W. Grant applications are also sought to develop software that adds significantly to the state-of-the-art in the simulation of such physical processes as intra-beam scattering, electron cooling, beam dynamics, transport and instabilities, electron or plasma discharge in vacuum under the influence of charged beams, etc.

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

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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) measurement devices/systems for cw beam currents in the range 0.1 to 100 μA with very high precision ($<10^{-4}$) and short integration times; (5) beam diagnostics for ion beams with intensities less than 10^7 nuclei/second; (6) non-destructive beam diagnostics for stored ion beams such as at the RHIC and/or for 100 mA class electron beams; and (7) devices that can perform direct 12-14 bit digitization of signals at 0.5-2 GHz and have bandwidths of 100+ kHz.

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16. NUCLEAR PHYSICS DETECTORS, INSTRUMENTATION AND TECHNIQUES

The Department of Energy (DOE) is interested in supporting projects that may lead to advances in detection systems, instrumentation, and techniques 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 laboratories and university programs. In addition, a new suite of next-generation detectors will be needed for the proposed Rare Isotope Accelerator (RIA), the energy upgrade at TJNAF, the proposed underground laboratory, the proposed luminosity upgrade at RHIC, and a possible future electron-ion accelerator. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

a. Advances in Detector Technology—Nuclear physics research has a need for devices to detect, analyze, and track charged particles, and neutral particles such as neutrons, neutrinos, photons, and single atoms. These devices include: solid-state devices such as highly segmented coaxial and planar germanium detectors, and silicon strip, pixel, and silicon drift detectors; photosensitive devices such as avalanche photodiodes, hybrid photomultiplier devices, single and multiple anode photomultiplier tubes, high-intensity ($\sim 10^{20}$ γ/s) gamma-ray current-readout detectors (e.g. Compton Diodes), photodiodes for operation at liquid helium temperatures with a signal-to-noise ratio comparable to a photomultiplier tube, and other novel photon detectors; detectors utilizing photocathodes for Cherenkov and UV light detection, and the development of new types of large area photo-emissive 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, drift electrodes with micromeshes, time projection chambers, and straw drift tube chambers; liquid argon and xenon ionization chambers and other cryogenic detectors; single-atom detectors using laser techniques and electromagnetic traps; particle polarization detectors; electromagnetic and hadronic calorimeters, including high energy neutron detectors; and detection systems for detecting the magnetization of polarized nuclei in a magnetic field (e.g., Superconducting QUantum Interference Device (SQUIDS) or cells with paramagnetic atoms that employ large pickup loops to surround the sample). Grant applications are sought to develop advancements in the technology of the above mentioned detectors.

With respect to solid state tracking devices, such as the segmented germanium detectors and the silicon drift, strip, and pixel detectors, grant applications are sought for: (1) manufacturing techniques, including interconnection technologies for high granularity, high resolution, light-weight, and radiation-hard solid state devices; (2) highly arrayed solid state detectors for neutron detection, with integrated electronics to read-out pulse height; (3) thicker (more than 1.5 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 charged particle and photon tracking devices, grant applications are sought for the development of: (1) position sensitive, high resolution, germanium detectors capable of determining the position (to within a few millimeters utilizing pulse shape analysis) and energy of the individual interactions of gamma-rays (with energies up to several MeV), hence allowing for the reconstruction of the energy and path of individual gamma-rays using tracking techniques; (2) hardware and software needed for digital signal processing and gamma-ray tracking – of particular interest is the development of efficient and fast algorithms for signal decomposition and improved tracking programs; (3) alternative materials, with comparable resolution to germanium, 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); (4) advances in more

conventional charged-particle 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); (5) high-resolution, gas-filled, time-projection chambers employing CCD cameras to perform an optical readout; (6) gamma-ray detectors capable of making accurate measurements of high intensities ($>10^{11}$ γ/s) with a precision of 1-2 %, as well as economical gamma-ray beam-profile monitors; and (7) for the RIA, next-generation high spatial resolution focal plane detectors for magnetic spectrographs and recoil separators, for use with heavy ions in the energy range from less than 1 MeV/u to over 100 MeV/u.

With respect to particle identification detectors, grant applications are sought for the development of: (1) inexpensive, large-area, high-quality Cherenkov materials; (2) inexpensive, position sensitive, large-sized photon detection devices for Cherenkov counters; (3) high resolution time-of-flight detectors; (4) affordable methods for the production of large volumes 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 (5) very high resolution particle detectors or bolometers based on semiconductor materials and cryogenic techniques. Of particular interest are detector technologies capable of measuring energies of alpha particles and protons with less than 5 keV resolution, allowing spectroscopy experiments using light charged particles to be performed in the same way as gamma spectroscopy.

b. Technology for Rare Particle Detection—Grant applications are sought for particle detectors and techniques that are capable of measuring very weak, rare event signals in the presence of significant backgrounds. Such detector technologies and analysis techniques are required in searches for rare events (such as double beta decay) and for applications in extending our knowledge of new nuclear isotopes produced at radioactive beam facilities. Rare decay and rare phenomenon detectors require large quantities of very clean materials, such as clean shielding materials and clean target materials. Neutrino detectors need very large quantities of ultra-clean water, for example. Therefore, grant applications are sought for new technologies to (1) fabricate or purify materials so they have ultra-low levels of radioactive contaminants and (2) measure the contaminant level of the ultra-clean materials. Lastly, grant applications are sought for new technologies to produce large quantities of separated isotopes, such as kg quantities of Ge-76 and other materials, which are needed for rare particle and rare decay searches in nuclear physics research.

c. Large Band Gap Semiconductors, New Bright Scintillators, and Calorimeters—Grant applications are sought to develop new materials or advancements for photon detection. Of specific interest are: (1) large band gap semiconductors such as (CdZnTe); (2) bright, fast scintillator materials ($LaBr_3$:Ce, HgI_2, AlSb, etc.); (3) plastic scintillators, fibers, and wavelength shifters; (4) cryogenic liquid scintillation gamma ray detectors (LXe); (5) Cherenkov radiator materials with indices of refraction up to 1.10 or greater with good optical transparency; and (6) new and innovative calorimeter concepts, including new materials, higher packing densities, or innovative fiber and absorber packing schemes.

d. Nuclear Targets—Grant applications are sought for the development of special 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; frozen-spin targets; active (scintillating) targets; windowless gas targets and supersonic jet targets for use with very low energy charged particle beams; liquid, gaseous, and solid targets capable of high power dissipation when high intensity, low emittance charged particle beams are used; and high-power targets with fast release capabilities for the production of rare isotopes. Grant applications are also sought for the production of ultra-thin films for targets, strippers, and detector windows. In particular, for the RIA, there is a need for stripper foils or films in the thickness range from a few micrograms per cm^2 to over 10 milligrams per cm^2, for use in the driver linac with very high power densities from uranium beams. Lastly, grant applications are sought to develop techniques for preparing targets of radioisotopes, with half-lives in the hours range, to be used off-line in both neutron-induced and charged-particle-induced experiments.

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***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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PROGRAM AREA OVERVIEW
DEFENSE NUCLEAR NONPROLIFERATION

http://www.nnsa.doe.gov/na-20

The Office of Defense Nuclear Nonproliferation, a component of the Department of Energy's National Nuclear Security Administration (NNSA), sponsors the development of many types of sensors, data collection systems, and data analysis systems to detect and deter the proliferation of weapons of mass destruction. The scope of this mission includes technologies for nuclear explosion monitoring, detection of the production of materials for nuclear weapons, and detection technologies to support the Nonproliferation of Nuclear Weapons Treaty (NPT).

17. TECHNOLOGY TO SUPPORT THE NUCLEAR AND RADIOLOGICAL NATIONAL SECURITY PROGRAM

The DOE/NNSA Office of Defense Nuclear Nonproliferation sponsors the development of many types of sensors, data collection systems, and data analysis systems to detect and deter the proliferation of weapons of mass destruction. The scope of this mission includes developing technologies to detect the production of materials for nuclear weapons, and to support the Nonproliferation of Nuclear Weapons Treaty (NPT). The Nuclear and Radiological National Security Program (NRNSP) develops technologies for detecting the radiation and chemical signatures associated with the production of nuclear weapons and nuclear weapons materials. This topic focuses on the development of detection systems and data analysis methods to address these NRNSP missions. **Grant applications are sought only in the following subtopics:**

a. Radiation Detection Technologies—Improved technologies must be developed and demonstrated to support onsite monitoring and verification of the NPT and other international arms control agreements. In particular, research is needed to demonstrate practical methods for detecting the diversion of small quantities of nuclear materials from known production sites of highly enriched uranium. Grant applications are sought to develop: (1) new scintillator materials, other suitable materials, and enabling technologies to substantially increase the performance (in resolution, sensitivity, and range) of currently available radiation detectors; (2) new safeguard practices for the improved detection, identification, and tracking of diverted fissile materials in transit, particularly when the materials are shielded; and (3) unattended sensor systems that integrate signature analysis and alarm functions into an expandable network based on state-of-the-art communication and internet protocol systems.

b. Detection and Monitoring of Nuclear Facilities—Detection networks and systems are needed to support the wide-area monitoring, detection, location, and characterization of non-declared nuclear activities. Grant applications are sought to develop an improved capability for the long-term monitoring of chemical and other signatures of nuclear materials production, e.g., effluents from uranium conversion and enrichment facilities, spent nuclear fuel reprocessing facilities, etc. Areas of interest include: (1) improved sample preparation, concentration, and ultra-sensitive (field or laboratory-based) analysis methods; (2) remote systems to exploit non-nuclear signatures such as optical, effluent, and process-specific signatures; (3) application of nanotechnologies to the detection of radiation and chemical signatures of nuclear proliferation; and (4) advanced, maintenance-free power sources that can independently power sensor equipment on site.

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Subtopic a: Radiation Detection Technologies

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***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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Subtopic b: Detection and Monitoring of Nuclear Facilities

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18. TECHNOLOGY TO DETECT NUCLEAR PROLIFERATION AND SUPPORT NUCLEAR NONPROLIFERATION AGREEMENTS

The DOE/NNSA Office of Defense Nuclear Nonproliferation sponsors the development of many types of sensors, data collection systems and data analysis systems to detect the proliferation of weapons of mass destruction. Within the office of Defense Nuclear Nonproliferation, the Proliferation Detection program develops and demonstrates innovative remote sensing and ground-based technologies for detection and analysis of foreign nuclear weapon programs, global nuclear materials production, the diversion of special nuclear materials, and the early stages of emerging proliferation of weapons of mass destruction. This topic focuses on the development of detection systems and data analysis methods to address these missions. **Grant applications are sought only in the following subtopics:**

a. Components for Synthetic Aperture Radar Systems—Grant applications are sought for one or more of the following electronic components to support the development of synthetic aperture radar systems:

(1) An advanced high-performance 10-bit Analog-to-Digital Converter (ADC) to facilitate new high performance radar designs. ADC systems must have a sampling frequency equal to or greater than 1.2 GigaSamples per second, greater than 9 effective number of bits (ENOB) at one fourth the sampling frequency (fs/4), a built-in 1:2 output demultiplexer, provisions for multiple ADC data clock synchronization (e.g., multi-channel sampling), low-voltage differential signaling (LVDS) compatible logic outputs, a ball grid array (BGA) package, and a built-in pseudo-random sequence generator for ADC interface integrity testing.

(2) An advanced high-performance 12-bit Digital-to-Analog Converter (DAC) with 1.2 GigaSamples/second, greater than 60 decibels (dB) spurious free dynamic range (SFDR) at one fourth the sampling frequency (fs/4), a built-in 2:1 input multiplexer, provisions for multiple DAC clock synchronization (e.g., quadrature synthesis), low-voltage differential signaling (LVDS) compatible logic inputs, a ball grid array (BGA) package, and an input FIFO (First-In, First-out) buffer with a low-data-rate serial output port for DAC interface integrity testing. Also, it would be very desirable to have two DACs on a single chip.

(3) Ultra-fast track-and-hold amplifiers capable of directly sampling 10 GHz signals. The intent is to employ the track-and-hold amplifier in a sub-Nyquist sampling architecture for a radar receiver. Requirements include 0.2 psec aperture stability, 1.5 GHz aperture rate, 0.5 Vpp maximum output signal amplitude, -45 dBc maximum peak harmonic and spurious distortion at maximum signal amplitude, 0.25 dB maximum gain flatness, 0 to +40 C operating temperature, and surface mount packaging.

(4) High-performance miniaturized gyros with a bias of one degree per hour or less. Airborne, high-performance real-time synthetic aperture radar (SAR) systems use inertial measurement units (IMUs) that contain three gyros and three accelerometers, and the size of the IMU is typically dominated by the gyros. Tactical-grade IMUs with gyro biases of 1 degrees/hour have been used successfully for fine-resolution SAR but are too large for proposed miniaturized SAR systems. Therefore, a small, lightweight gyro is needed for these systems. Tactical performance levels are desired, but grant applications proposing gyros with biases of 10-100 degrees/hour would be considered if tactical performance levels cannot be obtained. (However, the latter may be less likely to be selected.)

(5) A solid-state wideband microwave power amplifier module to replace tube-based transmitters for short-range applications. Ideally, the module would have at least 100 Watts of peak power at a 35% duty factor and a 3 GigaHertz instantaneous bandwidth centered at Ku-band (16.7 GigaHertz). Grant applications proposing somewhat lower performance would be considered, but with lower probability of selection. The module should be 15 cubic inches or less and should include microthermal technology (such as micro-heat-pipes) to control junction temperatures without sacrificing size.

(6) Wideband array antennas with a minimum of 3 GigaHertz bandwidth centered at the Ku-band (16.7 GigaHertz). Dual band operation over both X-band and Ku-band is desirable.

(7) Field Programmable Gate Array (FPGA) implementation of SAR image formation algorithms. The promise of the newest FPGA technology (such as the Xylinx Virtex 2 family) is that many sophisticated software algorithms could be programmed directly into FPGA firmware for an increase in processing compactness and speed. In particular, it is desirable to have the well-known SAR image formation algorithm, Polar Format processing, be programmed into FPGA components. This implementation must retain parametric flexibility and allow an image formation greater than 1000 by 1000 pixels at programmable resolutions.

(8) Light-weight mechanical pointing structures for antenna stabilization and pointing for radar systems based on unmanned airborne vehicles (UAV). The range of motion should include at least 270 degrees in azimuth, and 0 to 90 degrees from horizontal in elevation. In the third axis, plus and minus 20 degrees of roll is desired. Slew rates of at least 60 degrees/sec are required with less than 0.1 second settling time, and pointing accuracy should be within 0.1 degrees. Inertial stabilization is desired to minimize power requirements. Total gimbal weight must be less than 10 pounds, and the system should be able to support up to a 10 pound payload.

For further information or clarification of these requirements please contact Armin Doerry ((505) 845-8165, awdoerr@sandia.gov) at the Sandia National Laboratory.

b. Components to Improve Active Imaging Systems—Grant applications are sought for high-throughput optical filters (with throughputs of 5 cm^2-steradians or higher for apertures of no more than 5-10 cm) operating in the visible and/or near-infrared (400 nm - 3.0 μm) regions of the electromagnetic spectrum. Filters of interest must have a single bandpass of no more than 0.1 nanometers or multiple (three or more) widely separated bandpasses of 1 nanometer or less. Filter tunability would be useful, but is not a requirement.

Grant applications are also sought for photocathodes for advanced sensors for single photon detection and imaging in the 1.5-3 μm spectral region. Transmissive devices are contemplated, but novel devices with other geometries could be considered. Important characteristics include room temperature operation, high quantum efficiency (>10% at 1.5 μm, the wavelength of most interest), low noise (<1 nA/cm^2 at 25C operating temperature), and fast (< 1 ns) response. Uniformity, linearity, and such processing factors as resistance to contamination are also important. Customizable spectral responsivity would also be of interest.

Grant applications are also sought for the development of a compact, portable seed laser with short (less than 1 nanosecond) pulses, a narrow (less than 1 nanometer) spectral bandwidth, and an intermediate pulse repetition rate that is adjustable between 1 KiloHertz and 1 MegaHertz or wider. Pulse energy should be 10 nanoJoules or higher. Because further amplification and wavelength conversion is likely, a wavelength in the 1.0 to 1.5 micrometer range is desired. Lightweight, low power consumption, and small size (0.5 cubic feet or less for the laser, and a similar size for the associated power supplies/electronics), and high pulse contrast ratio are also very important. Technologies offering a pathway to shorter pulses, higher pulse energy, and/or more flexible pulse formats are strongly preferred.

Finally, grant applications are sought for compact power amplifiers for use with the laser oscillators described above. Output pulse energies must be 10 microJoules or higher. These amplifier systems must be of small size (0.5 cubic feet or less for the laser, and a similar size for the associated power supplies/electronics).

For further information or clarification of these requirements please contact Cheng Ho (505-667-3904, ho@lanl.gov) or David C. Thompson (505-667-5168, dcthomp@lanl.gov) at the Los Alamos National Laboratory.

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19. RESEARCH TO SUPPORT GLOBAL NUCLEAR EXPLOSION MONITORING

The Nuclear Explosion Monitoring Research & Engineering (NEM R&E) program is sponsored by the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) Office of Nonproliferation Research and Engineering. This program is responsible for the research and development necessary to provide the U.S. Government with capabilities for monitoring nuclear explosions. The NEM R&E program provides research products to the Air Force Technical Applications Center (AFTAC), which collects and analyses data from a network of seismic, radionuclide, hydroacoustic, and infrasound data collection stations. Within the context of one or more of these technologies, research is sought to develop algorithms, hardware, and software for improved event detection, location, and identification at thresholds and confidence levels that meet U.S. requirements in a cost-effective manner. Grant applications responding to this topic must demonstrate how the proposed approaches would complement and be coordinated with ongoing or completed work (see list of ongoing contracts https://www.nemre.nnsa.doe.gov/coordination) while improving capability.

Grant applications are sought only in the area of technologies for nuclear explosion monitoring, as described below.

a. Ground-Based Systems for Seismic Monitoring of Nuclear Explosions—Grant applications are sought for systems that will greatly improve the data availability for existing seismic stations while reducing operation and maintenance costs. Sensor data must be collected continuously with very low noise and transmitted to a data center in near real time with high reliability (>99%). Designs should include robustness, low-power, and reliable wireless communication from each sensor site to the central location over rough terrain. Grant applications to develop schemes for direct communication between the sensor site and the data center via satellite; the goal is to reduce satellite communication costs and the size and power demand of field components.

b. Ground-Based Systems for Radionuclide Effluent Monitoring of Nuclear Explosions—Grant applications are sought to improve radionuclide effluent monitoring systems through diagnostic/predictive statistical tools, including state-of-health data transmitted from existing ground-based systems. These tools should include mathematical algorithms to exploit signatures in the state-of-health data to detect, diagnose, and predict subtle hardware faults, thereby improving availability, lowering cost, and increasing the confidence in network operations. The software tools must be of proven reliability and take into consideration the wide extremes in the environmental conditions of the ground-based sampler/analyzers.

Grant applications are also sought to explore the use of beta-gamma coincidence to detect radioactive xenon isotopes, which could improve data availability, cost of operations, and, potentially, sensitivity. Existing systems utilize a plastic scintillator for beta detection and NaI for gamma detection in a system with 12 photo-multiplier tubes for 4 sample chambers. A system that is much easier to calibrate, i.e. having fewer photo-multiplier tubes per sample chamber, would be desirable. The replacement system should use one phototube per sample chamber and digital signal processing to extract beta and gamma signals from a "Phoswich"-configured, dual-scintillator detector. The system must withstand thermal and mechanical shock and allow the introduction and subsequent evacuation of ~10cc of gas sample with at most 0.5% memory effect between samples.

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4. *Proceedings of the 24th Seismic Research Review—Nuclear Explosion Monitoring: Innovation and Integration, Ponte Vedra Beach, FL, September 17-19, 2002*, sponsored by National Nuclear Security Administration/Defense Threat Reduction Agency; Los Alamos National Laboratory, 2002. (Report No. LA-UR-02-5048) (Available at: https://www.nemre.nnsa.doe.gov/coordination. On top menu, select "Previous SRR Proceedings," and then "2002.")

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PROGRAM AREA OVERVIEW
BIOLOGICAL AND ENVIRONMENTAL RESEARCH

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

The Biological and Environmental Research (BER) Program supports fundamental, peer-reviewed research in climate change, environmental remediation, genomics, systems biology, radiation biology, and medical sciences. BER funds research at public and private research institutions and at DOE laboratories. BER also supports leading edge research facilities used by public and private sector scientists across a range of disciplines: structural biology, DNA sequencing, functional genomics, climate science, the global carbon cycle, and environmental molecular science.

BER has a particular interest in the following areas:

(1) Climate Change research aimed at the development of advanced climate models to describe and predict the roles of oceans, the atmosphere, ice and land masses on climate over time and research to understand how carbon dioxide moves through the environment, ways to increase its removal from the atmosphere, and its impacts on the Earth's climate and ecosystems.

(2) Environmental Remediation research aimed at the development of advanced treatment options for nuclear waste, thereby extending the frontiers of biological and chemical methods for remediation, including the use of Earth's own

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microbe-based clean-up strategies; this research will yield science-based strategies to reduce the costs, risks, and time for cleanup of DOE sites contaminated from years of weapons research.

(3) Medical Sciences research aimed at the development of advanced imaging and other medical technologies including highly sensitive radiotracer detectors, radiopharmaceuticals, and new technologies such as an artificial retina that will give vision to the blind.

(4) Life Sciences research aimed at the development of innovative solutions along unconventional paths to solve challenges in energy and the environment. Research is focused on understanding nature's remarkable array of multi-protein molecular machines and the intricate workings of complex microbial communities; and on enabling us to use and even redesign these microbial machines and communities to produce clean energy, remove carbon dioxide from the atmosphere, and cleanup the environment. This program also supports research to understand the biological effects of low doses of radiation.

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. Optical Methods for Ultra-Sensitive Trace Gas Measurements—Continued improvement and development of innovative instrumentation are required for carrying out studies of the chemical processes in the troposphere. The complexity of the gas mixtures requires specificity and high sensitivity for adequate characterization and monitoring of key species on short time scales (seconds). Optical methods in the visible, near-infrared, and far-infrared allow this specificity but have suffered from lack of sensitivity for many key gases. Recent advances in light sources such as Quantum Cascade (QC) lasers and novel absorption techniques such as cavity ring-down spectroscopy (CRDS) are expected to improve the optical methods. Grant applications are sought to develop advanced optical methods, based on these new technologies, to measure the concentration of tropospheric trace gases in field and aircraft applications. Of particular interest are small, lightweight instruments that are low in power consumption for use aboard aircraft platforms and at surface measurement sites. Target species of particular interest include CO, ethene, acetylene, NO, NO_2, NO_3, nitric acid, formaldehyde, acetaldehyde, sulfur dioxide, nitrous acid, nitrous oxide, isoprene, methacrolein, methyl vinyl ketone, methyl nitrate, hydrogen peroxide, peroxyacetyl nitrate, methyl hydroperoxide, and peracetic acid.

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. Rapid response instruments that are capable of flux measurements with response times of one second or less are of particular interest. 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 and field measurement capabilities.

b. DIAL Water Vapor Profiling System—The accurate, continuous measurement of vertical profiles of water vapor content in the lower atmosphere remains

essential for atmospheric research and weather forecasting. Effective techniques currently range from rawinsondes to sophisticated microwave and optical techniques. The technology available for differential adsorption lidars (DIALs) to measure vertical profiles of water vapor has been improving. Grant applications are solicited to develop a highly portable, eye-safe, DIAL system for water vapor profiling that requires limited amounts of power and can operate unattended for long periods of time in the outdoor environment. Water vapor profiles up to at least two kilometers, during all times of the day, are required; even greater vertical probing distances are needed for some studies. Temporal resolution of one minute or less and vertical height resolution of 50 m or less are needed for routine observations; even better resolution is required for some special applications, e.g., the vertical profiling of the eddy fluxes of water vapor. Of particular interest are innovations that take full advantage of current laser and optical filter technology, utilize low-cost components and assembly, and maintain reliability of operation.

c. Measurement of the Size Distribution of Water Drops in Clouds—Existing *in situ* optical instruments, commonly used on research aircraft and at the surface, for measuring the drop size distribution of water clouds suffer inherent limitations. Because the measurement technology of these instruments (e.g., forward scattering and phase Doppler probes) is based on the light scattering properties of individual drops, the sample volume must be very small to prevent the coincidence of two or more drops from influencing the measurement. However, in clouds with low drop concentrations, these very small sample volumes make it difficult to obtain statistically significant drop samples when the drops are greater than approximately 50 μm in diameter. Yet, clouds with low drop concentrations and with drops greater than 50 μm are scientifically very important because this is the regime in which drizzle drops (i.e., drops with diameters from 50 to 200 μm) are formed. The formation of drizzle can lead to a rapid modification of the cloud drop size distribution, which in turn has a strong influence on a cloud's radiative properties, especially for marine and arctic stratus clouds. (For example, the formation of drizzle often leads to a rapid increase in effective drop radius and a corresponding decrease in number concentration, thereby decreasing the reflectance of a cloud.) Because stratus clouds cover a large portion of the earth, this process has a strong impact on the global radiative budget. Grant applications are sought to develop new instrument technology that is capable of providing statistically significant measurements of the size distribution of water drops with diameters from 3 to 200 μm in clouds that have a total drop concentration on the order of 10 to 100 per cubic centimeter. The new instrumentation should be capable of operation on research aircraft, tethered balloons, and on the ground without degradation in performance. The Phase I project should demonstrate the feasibility of the technology in the laboratory. In Phase II, an operational sensor should be built and tested on a research aircraft, on a tethered balloon, and on the ground. Potential commercial applications of the new sensor could extend to measurements of industrial and agricultural sprays.

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 14C/12C 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. 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 with an interest in collaboration should be aware of the DOE Consortium for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE) 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 possible 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. **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. Grant applications are also sought to design and demonstrate a new CO_2 analyzer with the following characteristics: (1) ability to determine the mole fraction of CO_2 in dry ambient air to a relative precision of 1 part in 3000 or better in one minute or less; (2) low gas use (30 cc/min or less) to minimize problems due to water vapor and to minimize consumption of reference gases, if employed; (3) robust enough for unattended field deployment for periods of half a year or longer; (4) cost less than $5000 when manufactured in quantity; and (5) not sensitive to motion.

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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 CO_2, development of lightweight (approximately 100 gram) sensors capable of measuring fluctuations of CO_2 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 CO_2 sensor via ballonsonde, other methods of remote sensing data acquisition by airborne or satellite platforms will not be considered.

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22. 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 enhancing natural mechanisms to slow the rate of atmospheric CO_2 increase, or in developing new approaches to mitigate the current atmospheric rise in CO_2 levels. A DOE report on carbon sequestration 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 focuses on biological mechanisms that offer the potential to slow the rate of atmospheric CO_2 increase, convert carb into relatively stable organic or inorganic forms, a utilize biosystems to achieve the simultaneo production of fuel or chemicals while sequesteri carbon. Research is needed to identify and quanti mechanisms for CO_2 transformation at rates that w lead to the long term fixation or sequestration of lar quantities of carbon (i.e., where10,000 to 100,000 tonn or more of carbon per year transformed or fixed considered significant) when applied to either natu (e.g., unmanaged terrestrial ecosystems) or manag biosystems.

Plants are known to fix CO_2 into biomass, and vario terrestrial and aquatic microbial populations also greenhouse gases (CO_2, CH_4 and CO), eith incorporating them into biomass or transforming them potentially useful organic compounds. Biochemic pathways have been identified in unicellul microorganisms that carry out the followi transformations: (1) CO_2 to CH_4 (methanogens); (CO_2 to organic material, *i.e.*, biomass and/or oth potentially useful byproducts (nonmethanogen autotrophs); (3) CO to organic material (variou including carboxydotrophs, and methylotrophs); and (CH_4 to organic material (methanotrophs). These desir activities are characteristic of bacteria, archaea unicellular algae, and yeasts. The usef microorganisms may be either photosynthetic (as a algae and blue-green bacteria) or nonphotosynthet (most microorganisms).

In some cases, microbial carbon fixation activity leads the direct production of long-chain hydrocarbons (up C_{36}). Both CH_4 and hydrocarbons are useful fuels, as H_2, which is also produced by various microorganisn such as autotrophs. This H_2-producing activity ma occur directly via carbon fixation, or indirectly by th reductive biotransformation of organic carbo sequestration products by other microbes. Alternativel some micro-organisms that are capable of fixing CC CH_4, or CO, may instead, when coupled to oth fermentative microbial cultures (e.g., bacteria or yeas in a two-stage process, transform the gaseous substrat to useful alcohols (e.g., ethanol or 2,3-butanediol Other two-stage processes can produce oxychemica that are themselves valuable commodity chemica (acetate, lactate, acetaldehyde, acetoin, etc.).

Grant applications must provide for a systemat evaluation of proposed biological mechanisms an carbon sequestration systems. Estimates of the amou of CO_2 transformed also must be provided, and an assumptions concerning quantities and conditions fo

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carbon fixation and sequestration must be clearly defined. Feasibility tests (analytical, bench, or field) performed in Phase I must demonstrate that the proposed approach, when scaled up, could theoretically result in a significant rate reduction in atmospheric CO_2 concentration, significant sequestered amounts of carbon, or the production of significant amounts of value-added food, fiber, chemicals, construction materials, or fuel products. Phase I should provide preliminary data on prospective rates and quantities of enhanced carbon transformation and sequestration with more comprehensive and peer-reviewed data sets developed in Phase II. Grant applications proposing only computer modeling without improvements in physical mechanisms or field approaches will not be considered.

The facilities and expertise of the DOE Consortium for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE) can be made available to potential SBIR applicants to this topic. The CSITE is 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). Scientists at Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, and the Joanneum Research Institute in Austria can also provide support to potential applicants. The DOE also supports carbon sequestration research at the National Energy Technology Laboratory (NETL). **Grant applications are sought only in the following subtopics:**

a. 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 sediments and in wood products of terrestrial ecosystems. Woody species, for example, sequester carbon as lignocellulose, which is a stored product for the lifetime of the tree. Also, 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 biotic and soil components of terrestrial ecosystems. Areas of particular interest include: (1) research on plant metabolic pathways or mechanisms that allow increased CO_2 fixation rates, achieved through conventional molecular or traditional genetic means, and leading to overall productivity increases; (2) novel technologies for managing vegetation (such as cost-effective nutrient management, forest regeneration, and ecosystem modification) to enhance carbon uptake and retention, thereby significantly increasing CO_2 fixation and C storage; (3) techniques for increasing the fraction of recalcitrant organic compounds produced during natural microbial conversion of plant biomass in soils, resulting in increased long-term C-storage; and (4) measurement techniques that would allow for the validation of technologies developed to enhance net long-term C sequestration in man-made and natural environments.

Proposed approaches should exhibit a capability to increase, or to measure increases of, carbon fixation or sequestration by at least 1 tonne per hectare per year. Grant applications should provide information about rates and quantities of carbon fixation or sequestration enhancement by the proposed technologies. Phase I must demonstrate basic feasibility and efficacy of proposed sequestration mechanisms, with the larger field-scale applications designed and tested in Phase II.

b. Development of Enhanced Carbon-Sequestering Biosystems—Previously-identified, naturally-occurring cultures have been shown to fix carbon along with the production of fuels or commodity chemicals. Grant applications are sought to further optimize these processes via one or more biotechnological techniques (strain improvement including the use of genetic engineering, culture medium optimization, novel reactor design, or improved reactor operation). Desired improvements should increase carbon sequestration rates by at least 50%. Grant applications should focus on: (1) the development of microbial cultures with improved carbon-sequestering abilities, (2) the development of improved reactors or their operating protocols configurations that support improved growth, or (3) a combination of (1) and (2). Phase I must demonstrate the improved carbon sequestration biosystem(s) on a bench scale. Larger, pilot-scale demonstrations would be tested in Phase II.

c. Production of Commodity Chemicals—Grant applications are sought to identify and characterize new one- or two-stage biosystems capable of fixing carbon along with the production of nonfuel commodity chemicals – acids, alcohols, and/or aldehydes. ("Stage" refers to a discrete microbial culture containing either a single organism or a consortium – two-stage cultures are operated sequentially. "Biosystem" refers to a culture grown in a bioreactor.) Although a single biosystem would not be expected to perform all of these tasks, a single stage biosystem that produced large amounts of

biosolids would still be of interest – provided that the biosolids could be used as petrochemical-sparing feedstocks for chemical production (either via traditional methods or as agricultural soil amendments via composting). For biosolids produced as chemical feedstocks, no special attributes are required. However, biosolids produced for agricultural purposes must be more resistant to subsequent biodegradation than typical cellulosic materials. Areas of interest include (1) the identification of new, naturally-occurring microorganisms with acceptable carbon-sequestering abilities; (2) the identification of novel configurations for growth of useful microorganisms at the expense of greenhouse gases, or (3) a combination of (1) and (2).

Proposed approaches based on these new biosystems must show significant potential for rapidly fixing large quantities of carbon. An acceptable carbon sequestration rate would be the consumption of at least 5 grams of carbon (expressed on an atom basis) per gram cell dry weight per hour, at an ambient temperature of at least 15 degrees C. This rate corresponds to a generation time of no less than approximately 24 hours. In the case of chemical production, the overall process must demonstrate a net CO_2 consumption through the formation of biomass as a by-product. (It is understood that CO_2 production, through normal cell metabolism, is unavoidable, but significant net yield of fixed carbon should be the design objective and performance measure.) Phase I must demonstrate basic feasibility and efficacy of the proposed carbon sequestration mechanisms on a bench scale. Larger, pilot-scale demonstrations with emphasis on yield performance would be tested in Phase II.

d. Production of Fuel Chemicals—Grant applications are sought to identify and characterize new one- or two-culture biosystems capable of fixing carbon along with production of fuel chemicals – H_2, CH_4, fuel hydrocarbons including oils, or fuel alcohols such as ethanol. Areas of interest include: (1) the identification of new, naturally-occurring microorganisms with acceptable carbon-sequestering abilities, (2) the identification of novel configurations for growth of useful microorganisms at the expense of greenhouse gases, or (3) a combination of (1) and (2). It is understood that no single biosystem would be capable of performing all of these tasks.

Proposed approaches based on these new biosystems must show significant potential for rapidly fixing large quantities of carbon. An acceptable carbon sequestration rate would be the consumption of at least 5 grams of carbon (expressed on an atom basis) per gram cell dry weight per hour, at an ambient temperature of at least 15 degrees C. This rate corresponds to a generation time of no less than approximately 24 hours. In the case of chemical production, the overall process must demonstrate a net CO_2 consumption through the formation of biomass as a by-product. (It is understood that CO_2 production, through normal cell metabolism, is unavoidable, but significant net yield of fixed carbon should be the design objective and performance measure.) Phase I must demonstrate basic feasibility and efficacy of the proposed carbon sequestration mechanisms on a bench scale. Larger, pilot-scale demonstrations with emphasis on yield performance would be tested in Phase II.

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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 and advanced imaging instrumentation. DOE is interested in innovative research involving medical technologies to facilitate and advance the current state of diagnosis and treatment of human disorders.

Principles of physics, chemistry, and engineering are being employed to advance fundamental concepts dealing with human health, to utilize the study of molecular interactions for a better understanding of organ function, and to 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 Advanced Medical Instrumentation program seeks to capitalize on the unique physical sciences and engineering 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, 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; and (2) new radionuclide imaging systems. **Grant applications are sought only in the following subtopics:**

a. Development of Novel Probes for Biomedical Applications—Grant applications are sought to develop improved and new probes (fluorescent, electron dense, vibrational tags, etc.) with optimum physico-chemical properties for visualization, tracking, assembly, and disassembly of the multiprotein complexes that execute cellular functions and govern both cell form and components. These multifunctional probes would measure structure, including post-translational modification, and would function in real time. Novel probes are also needed to enable rapid visualization and quantification of intracellular processes with high spatial resolution. Probes should be selective, non-perturbative, resistant to degradation, and have unique spectroscopic signatures. Grant applications must present unambiguous experimental systems to validate probe performance and demonstrate that the research will ultimately result in new sensors for medical applications. Several DOE national laboratories have developed considerable expertise in this research area and are available for possible collaboration.

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 emission computed 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.

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24. GENOMES TO LIFE, AND RELATED BIOTECHNOLOGIES

The Department of Energy (DOE) supports research to acquire a fundamental understanding of biological and environmental processes. This includes the display of genomes as DNA sequences, the functional characterization of gene products from humans and useful organisms, structural biology research using beam lines at synchrotron sources and other facilities, computational genomics, and the development of integrating information systems. This topic is focused on the goals of the Genomes To Life (GTL) program, namely, to develop a detailed understanding of the molecular machines of the cell and of their networking. Microbes with capabilities that can further several DOE programmatic missions are being used as the current subjects for these studies. The knowledge thus gained would enable both the public and private sectors to apply genome knowledge to the production of energy sources, promote environmental applications such as bioremediation and carbon sequestration, promote cleaner industrial processes using biotechnology, and enable increasingly effective computational models of the microbial cell. For some of the subtopics below, capabilities already exist in a few laboratories, but commercial involvement will be needed before the technology can be exported to the broader research community. **Grant applications are sought only in the following subtopics:**

a. Genome Scale Reagent Sets—There is an increasing availability of genomes as sequenced chromosomes with their constituent genes. These genes number in the thousands for bacteria and in the 10-100 thousand range for higher organisms. Each gene may give rise to numerous distinct mRNAs and proteins, through processes of alternative RNA splicing and post-translational modifications. Micro-arraying methodologies are enabling highly parallelized interrogations of these huge macromolecule collections. However, production and management systems are required to assure the availability of the numerous analytical reagents that are needed in small quantities. Grant applications are sought for: (1) systems that will produce thousands of affinity reagents (oligo-nucleotides, synthetic genes, antibodies, and other affinity reagents) in pico-molar quantities; (2) miniaturized delivery systems for such reagent sets; (3) reagent sets for quantitation of RNA splicing; and (4) candidate interferring RNAs for testing as regulatory agents.

b. Proteomics—A number of proteomics tasks are being pursued to achieve the goals of the GTL program. These tasks include high throughput production and purification of proteins, correlation of proteins with the genes encoding their primary structure, identification of protein isoforms encoded by the same gene, identification of memberships in functional complexes of proteins, and identification of the variations of proteome constituents under change to useful

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hysiological states. However, a number of obstacles re preventing the accomplishment of these tasks. For xample, several host-vector systems are available for ıe production of proteins encoded in a hyper-expressed ource gene; yet, for some source genes, the proteins fail ɔ fold into physiologically effective three-dimensional onformations (entrapment in insoluble inclusion bodies s one cause of such failures). Another difficulty is that ɔroteins targeted to membranes are problematic. Lastly, he lack of affinity reagents that bind to proteins in their ıative conformations adversely impacts structure, ɔrotein association, and function analyses. Therefore, grant applications are sought for the improved recovery and analysis of effective proteins. Areas of interest include: (1) the production of solubilized proteins in active confirmations with or without post-translational modifications; (2) the development of synthetic membranes or nano-structures enabling analyses of membrane proteins; (3) the development of improved affinity reagents; and (4) the development of reporting labels to enable the multiplexing of assays.

c. Instrumentation for Single Macromolecule Analysis and Control—Over the last decade, research laboratories have made substantial progress in developing instrumentation for the interrogation and manipulation of single macromolecules. Techniques include the use of optical-laser tweezers, atomic force microscopy, and single molecule fluorescence microscopy. Although the effectiveness of these techniques has improved steadily and the instrumentation is now robust, most of these single-molecule, biophysics instruments are locally built. The lack of commercial support has severely hindered the export of these technologies to the broader user community. Grant applications are sought to expand the commercialization of techniques, instrumentation, and software systems so as to enable the broader usage of single macromolecule analysis methods.

d. Informatics—The development of an effective computational model of the cell not only would contribute to the GTL program but also would have numerous applications, including the preliminary processing of genome scale data sets being generated by experimental groups. Grant applications are sought to improve one or more of the component software packages that have already been developed by laboratory groups, in order to enhance user friendliness and thereby support their broad export to the biologist community. Grant applications are also sought to develop novel software in support of cellular modeling tasks. Of particular interest are approaches related to: (1) systems biology, (2) the processing of proteomics and metabolomics data sets, (3) improved integration and or querying of heterogenous data sets, and (4) the automated development of cellular metabolic models from data sets on newly studied microbes.

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25. MEASUREMENT/MONITORING AND CHARACTERIZATION TECHNOLOGIES FOR THE SUBSURFACE ENVIRONMENT

The characterization and monitoring of soils, subsurface sediments, and ground water are important elements of Department of Energy (DOE) research efforts. Objectives include determining the fate and transport of contaminants 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 submitted to this topic 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 operate under field conditions with mixed/multiple contaminants and that can be deployed in 2-3 years will receive selection priority. 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.

For some of the following subtopics, collaboration with government laboratories or universities may speed the development of the measurement or monitoring technology. For example, the Environmental Molecular Sciences Laboratory (EMSL), a DOE scientific user facility located at the Hanford Site in Richland, WA, can provide analytical instrumentation and capabilities with direct application to sensor development and testing. Potential applicants for subtopics a, c and d are invited to review the web site for the Interfacial Chemistry and Engineering group (http://www.emsl.pnl.gov:2080/homes/ice/) and the Interfacial and Nanoscale Science Facility (http://www.emsl.pnl.gov/capabs/insf.shtml) at the EMSL. For subtopic b, potential applicants are invited to review the web site for the Savannah River Ecology Laboratory (SREL), located at the Savannah River Site in Aiken, SC. In addition to the potential sources for collaboration, scientists at SREL are involved in several on-going phytoremediation research projects (see references). Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements. **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 microorganisms in contaminated soils, sediments, or ground water 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. For this subtopic, the following radionuclides and metals are of interest: americium, arsenic, cesium, chromium, cobalt, mercury, plutonium, strontium, technetium, and uranium. In addition, chelators such as ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acid (NTA), and catechol derivatives (*e.g.*, disodium-1.2-dihydroxybenzene-3,5,-disulfonate) will be considered. Grant applications that address other contaminants will be declined.

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 speciation of contaminants in the subsurface; and/or (3) measure mass-transfer processes and rates within and among individual pores in the subsurface. Grant applications must provide convincing documentation (experimental data, calculations, etc.) that the sensing method is both highly sensitive (i.e., low detection limit) and highly selective to the target analyte (i.e., immune to anticipated physical/chemical/biological interferences.) Approaches that leave significant doubt regarding sensor functionality in realistic multi-component samples will be excluded from consideration.

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 (i.e., chemoluminescent or bioluminescent systems), enzyme or immunology-

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linked detection systems (e.g., enzyme-linked immunosensors incorporating colorimetric or fluorescent portable detectors), lipid characterization systems 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. Phytoremediation and Mycoremediation Monitoring of Soils and Sediments—New approaches to the restoration of contaminated areas – phytoremediation and mycoremediation – are being considered for use at DOE sites. Phytoremediation involves the use of living plants to extract and remove metals, radionuclides, and organic contaminants from soils, subsurface sediments, or ground water. Mycoremediation exploits the natural ability of fungi to extract contaminants from soils and concentrate them in fungal tissues above ground. Innovative methods are needed to monitor the performance or effectiveness of these and other bioremediation processes, particularly at the field scale. Performance or effectiveness monitoring will be needed to determine whether cleanup levels have been met. For this subtopic, the contaminants of interest include a number of metals and radionuclides (americium, arsenic, cesium, chromium, cobalt, mercury, plutonium, strontium, technetium and uranium), chelators, chlorinated organics, and ketones.

Grant applications are sought to develop technology for monitoring the following parameters of plants and fungi used in phytoremediation and mycoremediation, respectively: (1) the concentration and partitioning of contaminants in plant roots (sorbed or bound and internal), shoots, stems, and leaves; (2) the concentration and partitioning of contaminants in fungal vegetative vs. aerial mycelium; (3) root or mycelial depth, distribution, density, and diameter: (4) mortality, health, and vigor of plants or fungi (stress indicator); (5) photosynthetic rates in plants; or carbon assimilation rates in fungi; (6) leaf area and evapotranspiration, in plants; or fruiting body dimensions in fungi; and/or (7) plant or fungal tolerance or sensitivity to contaminants of interest.

Potential monitoring technologies could include any of the following techniques: (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 measurement, (6) chlorophyll fluorescence measurement, (7) Enzyme-linked immunosorbent assay (ELISA)-based, respirometric, or other biochemical measurement of metabolite production, and (8) molecular monitoring of 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.

c. Sensor Technology for Monitoring Tank Waste—Grant applications are sought for the long-term monitoring of gases or liquids released from, or contained within, tanks containing mixtures of contaminants. Sensors would be used to detect and/or quantify contaminants, or their degradation products, in off-gases, effluents, or other samples. Sensors could also be used *in situ* to monitor changes in waste chemistry during storage. Contaminants of interest include a number of metals and radionuclides (americium, cesium, chromium, cobalt, mercury, plutonium, strontium, technetium, and uranium); anions such as nitrate; chelators; extractants such as tributyl phosphate; chlorinated organics; and ketones. Relevant wastes are expected to contain more than one type of contaminant; therefore, the sensor technology must be both sensitive and specific for targeted contaminant(s). Development of robust sensors, capable of use with high-level waste, is encouraged. However, sensors suitable for use with other waste types (such as low-level, mixed or hazardous) are equally desirable.

d. *In Situ* Monitoring Systems to Facilitate the Use of Reactive Barriers—Several DOE sites have plumes in the subsurface that are contaminated with metals, organics, and/or radionuclides. The current approach to remediating these plumes involves pump-and-treat operations, a process that manages, but may not completely eliminate, the risks associated with the plumes. Another approach, which could be used along with pump-and-treat operations, involves the construction of barriers that react with the contaminant to prevent further migration of the plume contaminants. The reactions are intended to convert the contaminant(s) into non-mobile form(s) or to degrade the contaminant(s) into non-toxic material(s). (Additional information on reactive barriers can be found at http://www.gjo.doe.gov/perm-barr/ and http://www.rtdf.org/public/permbarr/default.htm.)

Systems are needed to monitor the performance and integrity of reactive barriers. The development and deployment of such systems involves numerous challenges. Technical challenges include determining appropriate indicator parameters for both the barrier and the contaminant plume of interest, ensuring the longevity and continued integrity of the monitoring system itself, identifying appropriate ways of communicating monitoring data and other information to and from the system, and determining reliable maintenance strategies and schedules for the systems. Additional challenges involve replacing conventional monitoring practices, often based on laboratory analysis of manually obtained samples, with strategies based on the use of automated, remote monitoring systems, and achieving acceptance of these new systems and strategies by regulators and stakeholders.

Grant applications are sought to develop *in situ* remote monitoring systems for reactive barriers. Proposed systems should include: (1) autonomous reporting *via* secure wireless communications to a central information processing facility; (2) low power requirements, preferably using on-site solar panels; (3) no need, or at most minimal need, to replenish reagents or other consumables; (4) zero, or at most minimal, production of secondary wastes; and (5) a capacity for self-testing and autocalibration. Methods for detecting the condition and/or efficacy of the barrier itself, rather than just the targeted contaminants are of particular interest; an ideal system would provide sufficient advance notice of impending barrier failure so that actions could be taken to prevent the failure. Of particular interest are monitoring systems for barriers intended to deal with any of the halogenated organic constituents, hazardous inorganic species (*e.g.*, RCRA metals) and radionuclides. Grant applications should clearly identify the types of barriers and contaminants being addressed, provide an explanation of the fundamental scientific principles underlying the proposed method(s), and identify the detection/sensitivity limits for the monitoring systems. Communications support for monitoring systems is available and, therefore, is not sought in this topic.

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12. Fact Sheet on Phytoremediation Research at the Savannah River Ecology Laboratory (SREL), 2002: http://www.uga.edu/srel/Fact_Sheets/phytoremediation.htm. (The primary point of contact is currently Dr. Lee Newman. See: http://www.uga.edu/srel/faculty.htm)

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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.

The responsibilities of DOE's Office of EM include the remediation of radioactive and toxic wastes to their original background levels and the deactivation and decommissioning (D&D) of thousands of contaminated facilities. With regard to site remediation, DOE needs to locate and remediate contaminated plumes to prevent groundwater contamination and potential off-site migration of the plume. New or improved technologies are sought to address issues related to materials for reactive barriers and for *in situ* monitoring systems to facilitate the use of reactive barriers. DOE also needs to reduce the volume of contaminated concrete and associated waste streams, therefore, new or improved technologies are needed to separate contaminates from concrete. Lastly, DOE needs to reduce risks to workers from potential exposures associated with decontamination and decommissioning activities; therefore, new or improved technologies are sought for remote cutting or sizing technologies and for multi-purpose remote platforms.

DOE's inventory of transuranic and mixed wastes include about 155,000 cubic meters of waste stored on some 30 DOE sites and another 450,000 cubic meters of buried waste – at least some of which is likely to require retrieval in the course of DOE's site cleanup program. Most of the stored inventory is contained in 55-gallon drums or other containers. Although some of the buried waste is similarly packaged, knowledge of the condition of these containers and their contents is limited. In addition, some of the waste was buried in containers with limited or no durability container (e.g., in plastic bags or cardboard boxes) or was buried without containment.

The following topic solicits grant applications for technologies to facilitate the management of buried transuranic and mixed waste. The subtopics provide more detailed descriptions of specific needs.

26. TECHNOLOGIES TO FACILITATE MANAGEMENT OF BURIED TRANSURANIC AND MIXED WASTE

Land disposal of untreated, chemically contaminated wastes was prohibited in the mid-1970s when the Resource Conservation and Recovery Act (RCRA) was enacted. However, prior to 1970, the Department of Energy disposed of substantial quantities of transuranic (TRU) waste in near-surface excavations (shallow land disposal). Some of these wastes were buried in containers that may be retrievable; some were buried in bulk. In addition, a quantity of pond and lagoon sludges and associated soil remains buried.

There are several options for dealing with this waste, depending on the degree to which it endangers the environment. Some of the waste buried at individual DOE sites may be left in place and monitored during long-term site stewardship programs. Other buried waste may be retrieved for treatment and disposition as TRU or mixed waste. Before decisions can be made, research is needed to address the challenges involved in locating and characterizing these materials. This topic address three problem areas related to the management of buried TRU and mixed wastes. **Grant applications are sought only in the following subtopics:**

a. Improved, Noninvasive Assessment Methods to Locate and Identify Buried Waste and Determine Whether or Not it is Containerized—The retrieval of buried waste and contaminated media generally involves excavating the entire area where the material is known or expected to be, a very time-consuming and expensive process. Before the waste can be retrieved it must be located and a preliminary characterization (at least) must be made of its condition. Research is needed on methods to improve object identification. Therefore, grant applications are sought to develop new technologies for locating and identifying specific objects (e.g., drums, gloveboxes) that are below ground and determining if they need to be retrieved. Areas of research interest include the improvement of object identification and image resolution (to determine if the contaminated objects are drums, boxes, rocks, etc), improvements in image analysis, and the development identification models and software.

b. Imaging Technology for Assessing the Condition of Buried Waste—After the buried waste is located, and prior to retrieval, it will be necessary to determine the condition of the waste or waste container. If the drums or other containers are intact, they can be retrieved and handled using processes developed for stored waste. The retrieval of breached containers or non-containerized waste would be more difficult. To minimize the number of processing steps and to ensure worker safety, a more detailed characterization of the waste containers and their content must be performed at the retrieval site. Grant applications are sought to develop imaging technology to identify and characterize objects below ground. Of particular interest is the characterization of buried waste containers and the determination of potential leakage. Approaches could be nonintrusive (preferred) or intrusive and could be coupled with chemical analysis. Nonintrusive approaches may include ground penetrating radar, magnetometry, acoustics, chemical sensing of near-surface air samples, neutron activation, radiological surveys, etc. An example of a minimally intrusive approach would be the utilization of small-diameter bore-holes to emplace equipment or sensors or collect samples.

Grant applications are also sought to develop methods to improve image resolution and object identification. Sophisticated image analysis and identification models and software should determine what waste is buried, the condition of the buried waste, the potential contamination of the soil surrounding the buried waste, and whether or not the buried waste is containerized or stabilized.

c. Long-Life, Reliable Sensors that can be Remotely Interrogated for Improved Monitoring of Buried Waste Disposal Sites—Smart sensors can improve the monitoring of buried waste sites. Grant applications are sought to develop smart sensors for monitoring buried waste sites in order to determine changes in the conditions (physical, chemical, radiological, or biological) of either the buried waste or the soil surrounding the buried waste. State-of-the-art improvements could make it possible to interrogate sensors from remote locations and provide remote, standoff detection of both chemical and radiological hazards. The sensors should be able to detect the physical changes in either the containers or the soil surrounding the buried wastes; or chemical, radiological, or biological changes in the surrounding area, which could indicate that the buried waste is migrating through the surrounding environment.

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6. *Performance Management Plan for the Accelerated Cleanup of the Hanford Site,* U.S. DOE Richland Operations Office and Office of River Protection, http://www.hanford.gov/docs/hpmp

7. *Accelerating Cleanup of the INEEL,* U.S. DOE Idaho National Engineering and Environmental Laboratory, http://www.inel.gov/environment/

PROGRAM AREA OVERVIEW
NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

http://www.nuclear.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 Generation IV Nuclear Energy Systems Initiative, http://gen-iv.ne.doe.gov/, seeks to develop and demonstrate of one or more Generation IV nuclear energy systems that offer advantages in the areas of economics, safety and reliability, sustainability, and could be deployed commercially by 2030; (2) 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; (3) 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; (4) 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; (5) 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 (6) 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.

27. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power provides over 20 percent of the U.S. electricity supply without emitting harmful air pollutants, including those that may cause adverse global climate changes. New methods and technologies are needed to address key issues that affect the future deployment of nuclear energy and to preserve the U.S. leadership in nuclear technology and engineering. This topic addresses several of these key technology areas: improvements in nuclear reactor technology for existing reactors; advanced instrumentation and control for very high temperature reactor applications; and advanced core/reactor physics computer simulations and modeling. **Grant applications are sought only in the following subtopics:**

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a. New Technology for Improved Nuclear Energy Systems—Improvements and advances are needed for reactor systems and component technologies that ultimately would be used in the design, construction, or operation of existing and future nuclear power plants and Generation IV nuclear power systems [See References 1-5]. Grant applications are sought: (1) to improve and optimize nuclear power plant systems, and component instrumentation and control, by developing and improving the reliability of advanced instrumentation, sensors, controls, thereby providing more accurate measurement of key reactor and plant parameters; (2) to improve monitoring of plant equipment performance and aging, using improved diagnostic techniques for in-service and non-destructive examinations; (3) for advanced instrumentation, sensors, and controls that can withstand temperatures in excess of 800 C for the very high temperature Generation IV reactor designs; and (4) for advanced reactor/core computer simulation methods including advanced reactor design model code development; coupled/parallel thermal-hydraulic-reactor physics tools; safety and performance evaluation methods; and engineering calculations for new and existing nuclear reactors, major reactor components, and reactor core and fuel assemblies. Please note that the following areas of investigation are NOT of interest and will be declined: concepts for complete or partial reactor plant designs; generalized thermal-hydraulics analysis (e.g. CFD or two-fluid codes) and probabilistic risk assessment tools or methods; nuclear power plant security or building/containment enhancements; and NRC licensing and site permit issues. In addition, grant applications that deal with nuclear materials, chemistry, and/or corrosion research are also not of interest for this topic and should be submitted instead under Topic 28.

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PROGRAM AREA OVERVIEW
BASIC ENERGY SCIENCES

http://www.sc.doe.gov/bes/bes.html

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.

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

8. MATERIALS FOR ADVANCED NUCLEAR ENERGY SYSTEMS

he Generation IV nuclear energy initiative is an ıternational collaboration to identify, assess, and evelop sustainable nuclear energy technologies that are ompetitive in most markets, while further enhancing uclear safety, minimizing the nuclear waste burden, and ırther reducing the risk of proliferation (reference 1). Many nuclear energy systems have been proposed to dvance the goals of the Generation IV program (see eferences 2-8), including designs that use liquid-metal oolants such as sodium and lead, gas coolants such as elium, water coolants such as supercritical water, and ıolten salt coolants. For these systems, operation at ıigher temperature has been identified as a means to mprove economic performance and to support the hermochemical production of hydrogen. However, the nove to higher operating temperatures will require the levelopment and qualification of advanced materials to ıerform in the more challenging environment. As part ıf the process of developing advanced materials for hese reactor concepts, a fundamental understanding of naterials behavior must be established and a database hat defines the critical performance limitations of these naterials under irradiation must be developed. A recent vorkshop details many of the research challenges for ıigher temperature materials associated with proposed Generation IV systems (reference 9). **Grant ıpplications are sought only in the following ubtopics:**

a. Advanced Radiation Resistance Ferritic-Martensitic Alloys—Because of their resistance to void swelling, 9 Cr and 12 Cr ferritic-martensitic steels are considered prime candidates for intermediate temperature reactors such as the proposed liquid metal and supercritical water concepts operating in the temperature range of 400-750°C. However, many ferritic-martensitic steels are limited by poor higher temperature creep strength, typically degrading at temperatures greater than 550-600°C (reference 10). Grant applications are sought to improve the creep strength of 9 Cr and 12 Cr ferritic-martensitic steels through alloying, dispersion strengthening, or precipitation hardening. Innovative alloys with protective coatings are also of interest. Proposed approaches must provide for (1) isotropic creep properties with strength greater than that of Sandvik HT9 steel, (2) a ductile to brittle transition temperature less than room temperature, and (3) a minimum plane-strain fracture toughness of $0.25\sigma_y$. Alloying elements that act as neutron poisons (e.g., boron) or that become highly activated in a neutron spectrum (e.g, cobalt) must be minimized or eliminated. Because the ferritic-martensitic steels likely would be used in conjunction with sodium-cooled, lead- or lead-bismuth-cooled, or supercritical water-cooled reactor concepts, approaches that optimize corrosion performance while achieving improved high temperature strength would be considered high priority. Lastly, approaches that also address irradiation performance are strongly encouraged.

b. Advanced Refractory, Ceramic, Ceramic Composite, or Coated Materials—Some Generation IV concepts aim for very high temperature (>900°C) operation. However, with the exception of limited data on SiC-based systems, the radiation resistance of construction materials subjected to very high temperatures has not been identified or proven. Grant applications are sought to develop advanced refractory, ceramic, ceramic composite, or coated materials that can meet the very demanding conditions required to operate at temperatures greater than 900°C in a fast spectrum nuclear energy system. For these conditions, the materials should have low thermal expansion coefficients, excellent high temperature strength, excellent high temperature creep resistance, and good thermal conductivity. For post-irradiation handling at lower temperatures, sufficient room temperature fracture toughness must be maintained. Additionally, the materials need to be easily fabricated and capable of being joined. Because the reactors operating in this temperature regime are expected to be helium cooled, the materials must have low erosion properties in flowing helium and be able to survive an air ingress condition. Because sustainable nuclear energy systems are likely to be based on fast spectrum systems, the materials must avoid low atomic mass components such as hydrogen and carbon. Because the high temperature strength and corrosion resistance may be difficult to

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achieve with a single material, composite or coated systems may be required. Finally, because sustainable nuclear energy systems may be based on fast spectrum (i.e., fast flux) designs, materials intended for fast reactor concepts should minimize the use of low atomic mass components such as hydrogen and carbon.

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29. ADVANCED FOSSIL FUELS RESEARCH

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from fossil fuels. In supplying this energy need, however, the Nation must address growing global and regional environmental concerns, supply issues, and energy prices. Maintaining low-cost energy in the face of growing demand, diminishing supply, and increasing

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environmental pressure requires new technologies and diversified energy supplies. These technologies must allow the Nation to use all of its indigenous resources more wisely, cleanly, and efficiently. These resources include inherently clean natural gas and the Nation's most abundant and lowest cost resource, coal. **Grant applications are sought only in the following subtopics:**

a. Hydrogen Fuels and Technologies—Clean forms of energy are needed to support sustainable global economic growth while mitigating greenhouse gas emissions and impacts on air quality. Hydrogen systems can provide viable, sustainable options for meeting the world's energy requirements in all energy sectors – transportation, buildings, utilities, and industry. However, hydrogen energy systems still face a number of technical and economic barriers that must be overcome for these systems to become competitive. For example, infrastructure barriers, particularly in the storage area, hinder the near-term application of hydrogen for transportation applications. Additionally, safety issues, both real and perceived, are concerns for acceptance of hydrogen by the general population. Because of these barriers, the use of hydrogen as an energy carrier is considered a mid- to long-term goal. Advances must be made in hydrogen production, storage, transport, and utilization technologies and in the integration of these components into complete energy systems.

This subtopic focuses on hydrogen production. Initially, hydrogen will be produced from fossil fuels because it will take some time before the production of hydrogen from renewables is cost-competitive. In particular, domestic coal can be a major source of hydrogen in the near- to mid-term. Research is needed to improve technologies that not only will lower the cost of producing hydrogen from coal but also will enable the sequestration of carbon. Therefore, grant applications are sought to develop advanced separation and cleanup technologies for the efficient production of hydrogen from coal, particularly for fuel cell applications. Areas of interest include improved gas cleanup, sulfur removal, and hydrogen separation processes.

b. Small Scale Continuous Hydrogen Generator as a Fuel Source for Power Units—A safe means to provide a controlled stream of hydrogen as a fuel for power units would be desirable because, essentially, only steam and nitrogen would be emitted from the combustion air. Since combustion emissions are one of the worst sources of pollutants, this would be a significant improvement. Therefore, grant applications are sought to design, evaluate, and test candidate hydrogen-fueled power unit systems.

The Steam-Iron Process, configured some years ago as a continuously operating two-reactor process, is one possible candidate. In its first reactor, granular Fe_2O_3 is reduced to the elemental state by reaction at an elevated temperature with a reducing material such as HC gas or liquid fuels. The elemental iron is transferred to the second reactor where it reacts with steam to yield Fe_2O_3 and hydrogen. The Fe_2O_3 is recycled. Although extensively studied in the 1990s through the pilot plant stage, the Steam-Iron Process was not scaled up to demonstration size because its projected economics as a commercial source of large quantities of hydrogen was unsatisfactory. However, it may be possible to reconfigure this process as a source of hydrogen for a power unit. For example, with suitable valving, one or more pairs of Fe/Fe_2O_3 columns could be alternately reduced by a fuel and oxidized with steam to produce hydrogen. The engine driven by the hydrogen fuel could be a gas turbine, a fuel cell-electric engine combination, or an adapted multi-cylinder engine. Other novel means of generating a controllable stream of hydrogen fuel are also of interest. Whatever method is proposed, the suitability of the process and its economics must be compared with (1) state-of-the-art schemes for producing hydrogen by reforming hydro-carbonaceous material with steam/oxygen and (2) at least one candidate type of commercial power unit.

c. Biogeochemical Carbon Sequestration/Conversion—Carbon sequestration is a relatively new approach to the stabilization of greenhouse gas concentration (i.e., new compared to the other two pathways – improving the efficiency of energy use and reducing the carbon content of fuels). Current approaches include the conversion of carbon dioxide to benign, stable compounds for long-term storage or to value added products for reuse. Grant applications are sought to develop practical methods to: (1) grossly accelerate the natural bioconversion of carbon dioxide to methane in geologic reservoirs by employing methanogen microorganisms as catalysts, as well as other geochemical reactants, (2) apply similar processes to the capture of carbon dioxide at large point sources, and (3) efficiently employ microorganisms and/or biomimetic catalysts to convert carbon dioxide in flue gas to intermediates that can be subsequently reacted to calcium/magnesium carbonates for terminal sequestration.

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d. Instrumentation and Sensors for Solid Oxide Fuel Cell (SOFC) Materials Science—The use of fuel cells for power generation offers the opportunity for high efficiency and nearly pollution free operation. SOFCs consist of an ionically conducting solid oxide electrolyte layered between catalytically active porous electrodes. The electrochemically active cells are configured into a stack involving gas seals and electrical interconnections. The systems operate at high temperatures (600 to 1000°C) and suffer from chemical and mechanical stability limitations (see references 1 and 2). The search for suitable materials involves the synthesis of functional layers and interfacial regions with enhanced electrochemical properties. Unfortunately, a fundamental understanding of fabricated SOFC structures is limited by the ability to adequately characterize the functional materials in an SOFC cell and stack. Traditionally, the evaluation of SOFC materials has involved techniques such as x-ray diffraction and cross-sectional electron microscopy for structural properties (reference 3) and electrochemical impedance spectroscopy for charge conduction measurements (reference 4). However, the ultimate development of economically viable SOFCs will require more advanced measurement techniques.

Grant applications are sought to develop innovative instrumentation and sensors to advance the scientific investigation of SOFC materials. Some of the important materials parameters that require measurement include: (1) depth and/or area resolved residual stress in a layered cell, (2) ionic vacancy distributions, (3) cracks and interfacial delaminations, (4) porosity distributions and gradients; (5) ionic and electronic conductivity profiles; (6) catalytic activity distributions, (7) electrical conductivity and structural integrity of thin oxide films on metal interconnects, and (8) small area defect characterization (such as images of gas pinhole or electrical shorts in electrolyte layers). Of particular interest are techniques and sensors that allow for *in situ* measurements; pre- and post-operation, non-destructive evaluation involving buried interfacial regions; and imaging techniques that can characterize spatial inhomogeneities with regard to charge transfer activity and transport, or its underlying functional materials properties. For the latter, a connection between image data sets and finite element modeling approaches should be made apparent, with the ultimate goal of validating SOFC performance models (reference 5). Grant applications also should demonstrate that the instrumentation and sensors, though focused on basic materials science, will have relevance to developers and manufacturers of optimized SOFCs.

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***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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30. 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 collaborative research centers 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 submitted to this subtopic must address improvements in electron beam instrumentation capabilities beyond the present state-of-the-art.

Grant applications are sought to develop stages, holders, and/or detectors with new capabilities for quantifying data and collection efficiency in electron beam instruments. Areas of interest include: (1) extremely stable holders and stages that allow long exposure/analysis times, with accurate tilting and alignment capability (to an angle accuracy ±0.005 degrees on two axes while maintaining eucentricity to within 20 nm); (2) fast CCD camera systems that allow electron imaging exposure times in the millisecond range and kHz frame rates; (3) high sensitivity electron imaging systems based on CCD technology that provide 16 bit dynamic range or better over large areas; and (4) improved electron and x-ray detectors that are robust and not susceptible to electron beam damage. Proposed approaches for electron detectors must show suitability for either low- or high-energy electrons, and address one or more of the following three aspects: high quantum efficiency, high spatial resolution, and high temporal resolution. Proposed approaches for x-ray detectors should show significant improvement in sensitivity or spectral resolution for elemental analysis in electron microscopes.

Grant applications are also sought to develop stages and holders with new capabilities for *in situ* experiments or sample manipulation in the transmission electron microscope. Stages and/or holders must provide for one or more of the following: (1) application of magnetic field up to 5000 Oe in the plane of the specimen, with capability to rotate field orientation in the specimen plane with respect to the sample; (2) manipulation or measurement of the sample using a 4-probe nanomanipulator, including capability to measure deflection or strain, or capability to apply electric fields or current; and (3) precision control of 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 ±0.005 degrees on two axes).

Grant applications are also 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 systems for automated data collection, processing, and quantification. Systems should include hardware and platform-independent software for data collection and visualization, including automated measurement and mapping of crystallography, internal magnetic or electric field, or strain, and for multi-spectral analysis. Software and quantification routines for image reconstruction and for interpretation of interference patterns/holography are encouraged.

Finally, grant applications are sought for extremely stable power supplies to improve lens stability in electron beam instruments. Power supplies should be capable of producing 15 amperes with current stability exceeding 0.1 ppm, or 5 amperes with current stability exceeding 0.05 ppm, and should exhibit voltage stability of 0.1 ppm in the range of 1 kV to 200kV.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 5 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

References:

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4. Majkrzak, C., ed., *Thin-Film Neutron Optical Devices: Mirrors, Supermirrors, Multilayer Monochromators, Polarizers, and Beam Guides, San Diego, CA, August 16-17, 1988,* Proceedings of the SPIE, Vol. 983, Bellingham, WA: SPIE, 1989. (ISBN: 0819400181)

5. *Technology and Science at a High-Power Spallation Source: Proceedings of a Workshop Held at Argonne National Laboratory, Argonne, IL, May 13-16, 1993,* Argonne National Laboratory, 1993. (Report No. ANL/IPNS/PROC-81937) (NTIS Order No. DE94009685) (See Solicitation General Information and Guidelines, section 7.1.)

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10. Williams, D. B. and Carter, C. B., *Transmission Electron Microscopy: A Textbook for Materials Science*, Vols. 1-4, Plenum Publishing Corp., New York-London, 1996. (ISBN: 0-306-45247-2)

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31. ENERGY STORAGE TECHNOLOGIES FOR ELECTRIC AND HYBRID VEHICLES

The commercial use of electric and hybrid electric vehicle technologies has been limited by the performance and excessive costs of power sources and storage devices. In conjunction with the Office of Basic Energy Sciences, the Office of Energy Efficiency and Renewable Energy is interested in identifying and developing innovative concepts for advanced energy storage devices (batteries) that will improve the performance, extend the life, and significantly reduce the cost of the vehicles.

Battery-powered electric vehicles (EVs) require energy storage devices with high energy density, and hybrid electric vehicles (HEVs) require devices that can deliver high power pulses. Advanced hybrids may require devices that both store significant energy and can deliver high power pulses. All of these devices must be able to accept high power recharging pulses from regenerative braking. For high energy density systems, the goal is to develop cells that provide at least 200 Watt-hours/kg (Wh/kg), 400 Wh/l, 400 W/kg, and 800 W/l; have a life of 1000 cycles at 80 percent depth of discharge; and have a calendar life of at least 10 years. For high power applications, the goal is to develop cells that provide peak power of 1500 W/kg or greater, have a cycle life of

at least 300,000 shallow cycles, and have a calendar life of 15 years. For all systems, materials to be utilized should be plentiful, have low cost (< $10/kg), be environmentally benign, and be easily recycled. Evaluation of the technology with regard to the above criteria should be performed in accordance with applicable U.S. Advanced Battery Consortium test procedures or Society of Automotive Engineers recommended practices (see references that follow).

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. Technologies that Facilitate the Use of a Lithium Metal Anode in a Rechargeable Battery—The use of lithium metal as the anode (negative electrode) in a rechargeable battery offers advantages over lithium-ion systems; these potential advantages include lower cost, higher energy density, and the option of using positive electrode materials that do not have to be pre-lithiated. Unfortunately, multiple discharges and recharges of a lithium electrode can result in the growth of metal dendrites and the formation of finely divided lithium particles. These phenomena limit the life and compromise the safety of any battery incorporating such an electrode. Therefore, grant applications are sought to develop novel technologies, such as (but not limited to) interfacial materials or electrolytes, that will allow the use of a lithium metal anode in a rechargeable battery that meets the cycle and calendar life requirements associated with vehicular use. Grant applications must address the theoretical basis of the proposed R&D effort, the probable cost of using the technology in vehicular batteries, and the impact of the technology on other performance parameters such as power capability – technologies that adversely affect the performance of other parameters are not likely to be adopted. The proposed approach must be evaluated by cycling a lithium/lithium cell in Phase I, with full electrochemical cells containing a lithium electrode developed in Phase II. (References 2 and 3 are particularly applicable to this issue.)

b. 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. Grant applications are sought to develop and demonstrate novel rechargeable couples that meet the criteria described in the introduction to this topic. Rechargeable battery couples that incorporate anodic active materials such as aluminum or magnesium are of particular interest because of their potential use in high-performance, non-aqueous batteries for electric and hybrid vehicles. Areas of interest include (1) the synthesis and/or characterization of ionic conducting polymers and gel electrolytes that can transport polyvalent ions; (2) development of electrolytes that are capable of conducting alkaline earth, other divalent cations, and trivalent transition metal ions; (3) development of cathodes composed of intercalation compounds that allow the rapid diffusion of polyvalent ions; and (4) development of novel non-lithium couples that do not involve a polyvalent species. In addition, grant applications related to novel, non-lithium couples that do not involve the movement of metal ions from the negative to the positive electrode are also of interest. Proposed approaches must be demonstrated in full electrochemical cells of at least 0.2 Ampere-hour in size. Reference 8 is one of many articles on this subtopic.

c. Technologies to Improve the Tolerance of Lithium-Ion Cells and Batteries to Abusive Overcharge—High energy and high power lithium-ion cells and batteries may be subject to inadvertent, abusive overcharge if the battery's charging control mechanism fails. Depending upon the failure mode, cells may experience charging voltages that exceed the design specification by as little as 100 millivolts or up to many volts. Even low levels of overcharge have been shown to make a cell more susceptible to thermal runaway. More extreme overcharge can produce rapid events such as venting with smoke and flames. Grant applications are sought to develop novel methods of improving the tolerance of lithium-ion cells to overcharge. Improvements must be demonstrated in cells of at least 0.2 Ampere-hour in size. Grant applications may focus on changes in one or more of a cell's basic components (anode, electrolyte, separator, and cathode), or on materials added to a "standard" cell. Any standard, commercially available lithium-ion cell, suitable for vehicular use, may be used as the basis for the changes/improvements. (Note: some commercially available cells are not suitable for vehicular use because they contain costly components, operate only at low rates, have relatively limited cycle or calendar lives, etc.) Investigators that do not have access to specific information about the components of commercially available cells may use the specifications published by the Advanced Technology Development Program for its Generation 1 and Generation 2 cells as a starting point (see references 4 and 5).

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Grant applications must be for novel research and development as defined in the introductory sections of this solicitation, provide a theoretical basis for the research, address the probable cost of using the technology in vehicular batteries, and address the impact of the technology on other performance parameters such as calendar life, power capability, and energy density – technologies that adversely affect these parameters are not likely to be adopted.

d. Non-carbonaceous Anode Materials for Lithium-Ion Batteries—Conventional lithium-ion cells use carbon-based materials for their anodes (negative electrodes). The use of carbon in these cells does offer some advantages (e.g., a potential very near that of pure lithium), but disadvantages include an irreversible capacity loss on the first charge and limited capacity for lithium in terms of both weight and volume. Grant applications are sought for the development of new materials (i.e., that are not a form of carbon) that can serve as the active component of the anodes of lithium ion cells. Grant applications must address the probable cost of using the material in vehicular batteries and the impact of the technology on other performance parameters such as calendar life, power capability, and energy density – technologies that adversely affect these parameters without commensurate benefits are not likely to be adopted. The novel materials must be demonstrated in full electrochemical cells of at least 0.2 Ampere-hour in size. Compatibility of the new anode material with other cell components (electrolyte, separator, and positive electrode material) must be demonstrated. (For this purpose, investigators may choose components described by the Advanced Technology Development Program for its Generation 2 cells (see references 4 and 5) or choose other components.)

References:

Please note: Paper copies of these references not available in the open literature or from NTIS. They may be obtained by addressing a request to Mr. Irwin Weinstock, Senior Engineer, Sentech, Inc., 4733 Bethesda Ave., Suite 608, Bethesda, MD 20814. Where available, locations of the documents on the Internet are given.

1. Links to the following manuals are all available at: http://ev.inel.gov/battery. These documents provide a good general basis for understanding the performance requirements for electric and hybrid electric vehicle energy storage devices.
   - FreedomCAR 42V Battery Test Manual
   - FreedomCAR Battery Test Manual for Power Assist Hybrid Electric Vehicles
   - PNGV Battery Test Manual, Revision 3
   - Electric Vehicle Capacitor Test Procedures
   - USABC Electric Vehicle Battery Test Procedure Manual, Revision 2

2. The internet site for the Batteries for Advanced Transportation Technologies (BATT) program at http://berc.lbl.gov/BATT/BATT.html includes quarterly and annual reports. This program addresses many long-term issues related to lithium batteries, including new materials and basic issues related to abuse tolerance.

3. Zhou, J., et al., "Interfacial Stability Between Lithium and Fumed Silica-Based Composite Electrolytes," *Journal of the Electrochemical Society*, 149(9):A1121-A1126, 2002. (Addresses issues related to the formation of Li dendrites.) (ISSN: 0013-4651) (Available via Electrochemical Society Web site at: http://ojps.aip.org/JES/?jsessionid=298462105948920494 3. On menu at left, select "Browse all JES issues," and then "Volume 149." Scroll down to September 2002, Issue 9, and select either TOC, from which you may access article.)

References 4 and 5 discuss issues related to more mature, high power, lithium-ion batteries. They include information about cell chemistries that have proven to be useful model systems for these applications along with discussions of issues related to abuse tolerance and cell life.

4. *FY 2000 Progress Report for the Advanced Technology Development Program,* U.S. DOE, Office of Advanced Automotive Technologies, December 2000, http://www.cartech.doe.gov/pdfs/FC/97.pdf

5. *Advanced Technology Development (High-Power Battery): 2001 Annual Progress Report,* U.S. DOE, Office of Advanced Automotive Technologies, February 2002 http://www.cartech.doe.gov/pdfs/B/196.pdf

6. Information about requirements for vehicular batteries, separators for lithium-ion batteries, and abuse testing can all be found at the USABC section of the USCAR internet site. Go to http://www.USCAR.org; click on "Teams"; scroll down and click on "United States Advanced Battery Consortium (USABC)". This site provides a second source for many documents found at reference 1.

7. The abuse test procedures, developed for FreedomCAR by Sandia National Laboratories may be accessed directly at: http://www.uscar.org/consortia&teams/USABC/SAND99-0497%20USABC%20Safety%20Manual.pdf

8. Amatucci, G. G., et al., "Polyvalent Intercalation Batteries, a Step into Next Generation Energy Storage," presented at the 198th Meeting of the Electrochemical Society, Phoenix, AZ, October 22-27, 2000, Abstract No. 215, *Meeting Abstracts*, Vol. MA2000-2, Electrochemical Society, 2000. (ISSN: 1091-8213) (Paper published under new title: "Investigation of Yttrium and Polyvalent Ion Intercalation into Nanocrystalline Vanadium Oxide," *Journal of the Electrochemical Society*, 148(8):A940-A950, 2001. (ISSN: 0013-4651) (Available via Electrochemical Society Web site at: http://ojps.aip.org/JES/?jsessionid=298462105948920494 3. On menu at left, select "Browse all JES issues," and then "Volume 148." Scroll down to August 2001, Issue 8, and select either TOC from which you may access article.)

32. INNOVATIVE RESEARCH FOR THE HYDROGEN ECONOMY

Clean and secure forms of energy are needed to support sustainable economic growth while mitigating greenhouse gas emissions and impacts on air quality. To address these challenges, the President's National Energy Policy and the U.S. Department of Energy's (DOE's) Strategic Plan call for expanding the development of diverse domestic energy supplies. In his February 28, 2003, State of the Union address, President Bush expressed a goal to reverse America's growing dependence on foreign oil by developing commercially-viable, hydrogen-powered fuel cells to power automobiles, homes, and businesses with near-zero pollution or greenhouse gases. The President's new Hydrogen Fuel Initiative proposes to provide more than $1.2 billion in funding over the next five years to accelerate the development of the technologies and infrastructure necessary to achieve this goal. Working with industry, the DOE has developed a national vision for moving toward a hydrogen economy. To realize this vision, the U.S. must develop and demonstrate advanced technologies for hydrogen production, delivery, storage, and use. This topic addresses two important concerns for the hydrogen economy: the production of hydrogen from biomass and the utilization of Polymer Electrolyte Membrane (PEM) fuel cell technology. **Grant applications are sought only in the following subtopics:**

a. Modification of Biomass Composition through Plant Science—One of the advantages of hydrogen is that it can be produced from a variety of feedstocks and process technologies. Renewable biomass is an important potential feedstock because its use would be carbon-dioxide neutral relative to climate change concerns. Ultimately, the ability to produce hydrogen from biomass competitively will require lower feedstock costs. Examples of the desired traits of these feedstocks include increased yield, fast growth, less input requirements, and the ability to withstand stresses such as drought. Currently there is a lack of understanding of plant biochemistry, as well as inadequate genomic and metabolic data on potential crops. Grant applications are sought to further the understanding of the metabolic pathways for biomass crops and to modify these pathways in order to achieve step-change improvements in the above desired traits. In addition, grant applications are sought to genetically engineer the introduction of process-active cellulases and/or hemicellulases into the cell walls of biomass feedstock crops in order to enable the low cost hydrolysis of biomass to sugars.

b. Hydrogen Fermentation—The fermentation of sugars produced from biomass is a biomass-based production option that has not been extensively explored. This route to hydrogen production would be valuable because greenhouse gas emissions would be near zero. A few micro-organisms have the capability to produce hydrogen through the fermentation of carbohydrate (sugar) feedstock. However, known hydrogen production rates are far too low to be of practical interest. Therefore, grant applications are sought to significantly increase the rate of hydrogen production by the micro-organism fermentation of sugars generated from biomass.

c. Fuel Cell System Coolants and Membranes—PEM fuel cell technology is under development for a variety of applications, including light-duty transportation, portable power, distributed generation, and auxiliary power units. Much of this work is focused on cost reduction and performance enhancement to meet stringent targets for durability, specific power, power density, efficiency, and cost. Further work is sought to address specific component needs that ultimately aid in the development of cost-effective fuel cell systems. This subtopic address two of these needs: improved coolants and lower cost membranes.

Grant applications are sought to develop improved fuel cell system coolants that operate at elevated temperature (120°C), have very low electrical conductivity (less than

2.0 microsiemens/cm), are compatible with other materials in the coolant loop, and are non-flammable (i.e., have a very high flash point). In addition, the advanced fuel cell coolants also should have good thermo-physical properties (viscosity, heat capacity and thermal conductivity), a low freezing point (<-40°C), and low cost.

The high cost of the fluorinated polymers used to produce the membrane in PEM fuel cells is one of the major barriers to fuel cell commercialization. Polymer electrolyte membranes typically are composed of poly (perfluorosulfonic) acid, and the synthesis of the polymer includes a costly fluorination step. Grant applications are sought to develop novel membranes that are less than fully fluorinated, yet maintain high performance. The new membrane must be able to tolerate an acidic environment, perform under standard operating conditions, and cost no more than $5/kW.

d. Innovative Fuel Cell Concepts—Typical PEM fuel cell configurations include multiple cells that are stacked to achieve adequate working voltages and are fueled by hydrogen and air. Grant applications are sought to develop alternative, innovative PEM fuel cell configurations and concepts that address niche markets or employ unique technology that show promise for commercialization in the long-term. Areas of research interest include but are not limited to applications from biotechnology, microtechnololgy, or nanotechnology; unique cell design; and alternative concepts for membrane conduction. Proposed approaches should clearly demonstrate the potential benefits compared to conventional fuel cell technology.

References:

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2. *Vision for Bioenergy and Biobased Products in the United States*, Biomass Research and Development Technical Advisory Committee, October 2002. (Full text available at: http://www.bioproducts-bioenergy.gov/pdfs/BioVision_03_Web.pdf)

3. *Roadmap for Biomass Technologies in the United States*, Biomass Research and Development Technical Advisory Committee, December 2002. (Full text available at: http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf)

4. Himmel, M. E., et al., "Cellulases: Structure, Function, and Applications," Chapter 8, *Handbook on Bioethanol: Production and Utilization*, pp. 143-161, Washington, DC: Taylor & Francis, 1996. (ISBN: 1560325534) (See also *Cellulase Enzyme Research* at: http://www.ott.doe.gov/biofuels/cellulase.html)

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10. *National Hydrogen Energy Roadmap*, U.S. Department of Energy, November 2002. (Full text available at: http://www.eere.energy.gov/hydrogenandfuelcells)

11. *Hydrogen, Fuel Cells & Infrastructure Technologies Program: Multi-Year Research, Development and Demonstration Plan*, June 3, 2003 Draft, U.S. DOE Office of Energy Efficiency and Renewable Energy. (Full text available at: http://www.eere.energy.gov/hydrogenandfuelcells/mypp) (Final version scheduled for release in October 2003)

12. *FY 2002 Progress Report for Hydrogen, Fuel Cells, & Infrastructure Technologies Program*, U.S. DOE Office of Energy Efficiency and Renewable Energy, November 2002. (Full text available at: http://www.eere.energy.gov/hydrogenandfuelcells/annual_report.html)

33. NANOTECHNOLOGY APPLICATIONS IN INDUSTRIAL CHEMISTRY

The U.S. chemical industry is poised to apply many of the recent discoveries in nanotechnology, undertaken at universities and national laboratories, which may have an important influence on the manufacture and uses of chemicals and materials. In this topic, small businesses are encouraged to take advantage of these discoveries by conducting further R&D, leading to marketable products of importance to the U.S. chemical industry. The subtopic areas focus on nanomaterials research in catalysis, on polymers and polymer manufacture, on composite materials, and on new materials with special properties that mimic properties of living organisms (i.e., "biomimetics" applications). Grant applications must demonstrate a significant energy benefit, either from saving energy in manufacture, conserving materials, or providing longer life in applications. Grant applications also must demonstrate how these nanotechnology innovations will be introduced into the marketplace in conjunction with major chemical companies that have capabilities for widespread technology implementation and manufacturing. **Grant applications are sought only in the following subtopics:**

a. Nanomaterials with Catalytic Activity—Recent discoveries suggest that some materials with nanosized features may exhibit novel heterogeneous catalytic activity. Grant applications are sought to develop new nanoscale materials with catalytic properties. Chemical transformations of interest include, but are not limited to isomerizations, halogenations, oxidations, reductions, stereospecific transformations, or combinations of these. Proposed approaches must demonstrate that (1) the materials exhibit catalytic behavior only when their functional properties are imparted at the nanoscale, and (2) the intended products of the chemical reactions have commercial value. Partnership with chemical companies that have the manufacturing capabilities needed to bring the technology to widespread commercial application is strongly encouraged.

b. New Nanoscale Polymer Materials, Polymer Composites, and Polymer Processes—Recent research has shown that polymer materials with controlled nanocrystalline features may exhibit special or new properties that are not exhibited otherwise when the polymer material's nanosize features are not controlled. Furthermore, a composite material comprising both polymers and nanosize organic or inorganic substances could exhibit useful properties that are not exhibited by the polymer alone. Grant applications are sought to develop novel polymer processes with the potential to control features of the polymer at the nanoscale, resulting in polymer materials that have properties unmatched by any other materials. (Examples of such naturally occurring processes include the spinning of a web by a spider or the clotting of blood.) Grant applications should (1) address commercial applications or markets for proposed approaches, (2) demonstrate a careful review of the relevant scientific literature, and (3) address possibilities for forming partnerships with industrial chemical companies willing to assist in the development and application of the technology.

c. Development of Materials with Structure or Function Derived from Analogy with Properties Exhibited by Living Systems ("Biomimetics") — Grant applications are sought to develop materials that, due to the nanoscale features of the material, mimic some of the remarkable properties exhibited by living organisms. Such properties include self-repair, unusual hardness or strength or both, novel optical or electromagnetic behavior, or unusual transport properties for heat or mass. Grant applications must identify: (1) the novel biomimetic features to be developed; (2) the basis in nanoscience for the proposed materials development; (3) reasonable commercial applications for the new materials, and how these applications would save energy or materials or both in their intended use; and (4) a chemical industry partner that would participate in the development of the materials and that has the manufacturing capability to bring the materials to the marketplace.

d. Nanomaterials and Specialty Products Chemistry—In addition to the catalysts sought in subtopic a above, grant applications are sought to develop new products, based on nanoscience and nanotechnology, for use in specialty chemicals markets. These products include adhesives, antoxidants, biocides, corrosion inhibitors, dyes, flame retardants, flavorings and fragrances, specialty coatings, surfactants, and water-soluble polymers. Grant applicants must identify (1) specialty chemicals markets that will use the new materials, (2) energy benefits to be obtained from using the new materials, (3) the basis in nanoscience for the

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properties of the new materials, and (4) a specialty chemicals manufacturer that is prepared to assist in the commercialization of new materials technology.

References:

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34. 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 fo particular applications with outstanding economic compared to existing technology. Proposed efforts mus include the development of membrane reactor material with improved reliability and performance (e.g., bette selectivity, permeability, stability) as well as th development of unique approaches for engineering th membrane contacting devices. Grant applications tha simply apply membrane technology to existing reacto 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 the 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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35. SOLID STATE ORGANIC LIGHT EMITTING DIODES FOR GENERAL LIGHTING

This topic provides small businesses with an opportunity to carry out substantially novel research and development on the fabrication, processing, and characterization of solid state organic light emitting diodes (OLEDs) associated systems suitable for general lighting. Many researchers believe that solid state lighting represents an unparalleled opportunity to achieve major energy conservation in general illumination applications with attendant benefits in pollution reduction. While the final form of the solid state lighting of the future remains unknown today, there are several promising approaches including the subject of this topic, OLEDs. However, to achieve the important benefits typically associated with solid state lighting, key technical milestones must first be achieved. Some of these have already been defined and include: (1) major efficacy improvements at all wavelengths to obtain high efficiency white-light sources; (2) major cost reduction of practical device structures and form factors to be competitive with traditional light sources; (3) development of a new support infrastructure including powering, fixtures, etc.; and (4) identification of new approaches to lighting enabled by OLEDs such as "smart" light sources. These and other issues have been addressed in several recent workshops sponsored jointly by the Department of Energy (DOE), the Optoelectronics Industrial Development Association (OIDA), and the National Electrical Manufacturers Association (NEMA) in collaboration with a number of industrial, academic, and national laboratory participants.

To achieve the price ($3.00 per 1000 lumens) and performance (90 lumens per watt) required to enable the wholesale energy conservation sought in general illumination applications, quantum leaps in device performance are needed. To realize very large increases in performance, research directed at breakthrough opportunities is required. Thus, applications should be submitted under this topic **only** if the research represents a **significant** advance in materials or in processing and characterization that will lead ultimately to high-quality OLEDs capable of producing white light. Grant applications will be declined if they are limited to a minor or incremental improvement of an existing material or process. Also note that grant applications for research associated with other types of LEDs or other advanced lighting systems will not be considered under this topic; such systems may be the subject of topics submitted by other DOE programs within this solicitation. **Grant applications are sought only in the following subtopics:**

a. Device Synthesis and Architecture—Grant applications are sought to develop methods for improving the synthesis and architecture of OLEDs devices. Areas of interest include: (1) cost-effective, continuous deposition processes that can be scaled-up for large area coatings; (2) novel substrate and electrode materials; and (3) novel device architecture designs that are practical for large-scale manufacturing and/or that simplify the layer structures while increasing device performance.

b. Device Efficiency—Grant applications are sought to achieve higher OLED device efficiency, which can be characterized by its quantum efficiency, luminous efficiency, and luminous yield. Some potential areas of interest include: (1) reduction of injection barriers and balancing charge injection; (2) searching and developing new efficient emitters and activation catalysts; (3) researching new methods to increase internal quantum efficiency by employing phosphorescence, fluorescence, or other luminous molecular processes; and (4) developing new methods, device geometries, and materials for more efficient light extraction to yield higher external quantum efficiency.

c. Reliability and Lifetime—Grant applications are sought to improve the lifetime and reliability of OLEDs devices. Areas of interest include, but are not limited to: (1) characterization of the degradation mechanisms; (2) understanding the role and evolution of organic and inorganic impurities in OLEDs; and (3) new schemes, materials and geometries for device encapsulation and sealing from environmental contaminants.

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PROGRAM AREA OVERVIEW
ENERGY EFFICIENCY AND RENEWABLE ENERGY

http://www.eere.energy.gov

The mission of the Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that enhance energy efficiency and productivity; bring clean, reliable, and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

In order to accomplish this mission EERE has streamlined and integrated its program and business management by creating 11 programs to most effectively address the needs of the industry, transportation, buildings and power sectors: Biomass; Buildings; Distributed Energy and Electricity Reliability; Federal Energy Management; FreedomCar and Vehicle Technologies; Geothermal; Hydrogen, Fuel Cells, and Infrastructure Technologies; Industrial Technologies; Solar Energy Technology; Wind and Hydropower Technologies; and Weatherization and Intergovernmental.

One of EERE's core mission priorities is to engage and partner with the small business technology sector, in so doing, "leapfrog the status quo" by facilitating the development of new technologies that will dramatically reduce or end dependence on foreign oil; increase the viability and deployment of renewable energy technologies; increase the reliability and efficiency of electricity generation, delivery, and use; increase the efficiency of buildings and appliances; and increase the efficiency/reduce the energy intensity of industry.

It is estimated that the energy technologies and practices supported by the EERE programs have saved Americans billions of dollars in energy costs over the past decade. These savings are projected to dramatically increase as emerging and new energy technologies are developed and commercialized. These energy savings are accompanied by parallel reductions in emissions and 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.

36. NEW TECHNOLOGIES FOR GENERAL ILLUMINATION APPLICATIONS

Electricity consumed for general lighting applications in commercial and industrial buildings, residences, and outdoor applications represents about 22% of total U.S. electric energy production. As new, imaginative applications for lighting appear on the marketplace, lighting is predicted to continue to grow as an end use of electricity. Yet, despite concentrated efforts from both

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government and industry, the efficiency of converting electric energy into visible light by commercial light sources has increased only incrementally over the last three decades. Even the most efficient of today's lighting systems convert only about 30% of electrical energy into useful visible light. While there have been some significant recent advances in light sources, such as the compact fluorescent lamp, no truly revolutionary light sources have been developed and commercialized since the mid 1960s. Increases in lighting system efficiency have come primarily by substituting one type of lamp for another and from the addition of sophisticated controls. In spite of these efficiency increases, the overall installed base of general illumination in U.S. buildings is inefficient, especially in comparison to other buildings systems. However, the potential for substantial increases in light source efficiency is significant. Within the Office of Buildings Technologies, the Department of Energy maintains an active program to explore new methods by which high quality electric light can be produced with less energy and less environmental impact. The technical potential exists to increase light production efficiency by a factor of two or more. To realize this exceptionally high level of performance, with the attendant energy conservation potential, major advancements in basic light producing technologies must be made. **Grant applications are sought only in the following subtopics:**

a. Advanced High Intensity Discharge Lighting—Approximately 17% of the total energy consumed by electric lighting is by high intensity discharge (HID) sources that produce nearly all the lighting service in outdoor applications, about 30% in industrial applications, and about 10% in commercial spaces. There are three basic types of HID lamps in service today: mercury vapor, metal halide (MH) and high pressure sodium (HPS). All require ballasts and each has certain performance attributes for specialized applications such as street lighting, parking lots, high bay industrial lighting, and sports complexes. In addition, the replacement of conventional lamps, including incandescent "A-Line" lamps, with new, improved HID lamps represents an additional energy conservation opportunity. Although technological advances, particularly premium light engines and electronic lamp ballasts, have provided significant increases in energy efficiency compared to standard HID lamps, these advances have not led to the expected increases in sales.

The most energy efficient metal halide lamps use a premium light engine (the part of lamp enclosed by the quartz envelope containing the working gasses and electrodes under high pressure) that costs more than the standard light engine. The premium light engine is not only more efficient than the standard design, it also produces light with more desirable color attributes and less lumen depreciation, making it more life cycle cost attractive. These premium lamps are marketed as "Energy Efficient" because they replace a standard lamp by producing the same light with less power (e.g., a 360 W "Energy Efficient" lamp replaces a standard 400 W lamp, and so on). "Energy Efficient" lamps have been on the market for a number of years but have failed to experience significant market penetration, generally due to their higher first cost price differential compared to standard HID lamps (although compelling argument can be made in favor of "Energy Efficient" lamps on the basis of total life cycle cost).

Lamp ballast designs also can make a significant difference in HID system efficiency. Today, numerous manufacturers offer a line of electronic ballasts, but volume sales are almost exclusively conventional electromagnetic products. Adding increased functionality to the lamp-ballast designs may produce even more energy reductions as well as make the lamps more marketable. Some concepts for increasing HID lamp system functionality include: instant on, limited dimming, uniform lumen and color temperature, and networked controls integration.

Grant applications are sought to develop novel HID lamp designs with improved performance, in order to reduce first costs and simultaneously increase life cycle cost competitiveness (by increasing lamp lifetime, lumen maintenance, or lamp efficacy). Approaches of interest include less costly methods of manufacture that also produce a desirable reduction in cost, novel ballast designs that increase efficiency beyond presently available designs, and energy efficient system designs that add functionality and/or can replace conventional light sources (such as incandescent lamps).

b. Advanced Fluorescent Lamp Technology—Fluorescent lighting consumes about 41% of the total energy consumed in lighting and is especially prominent in commercial and industrial spaces where it produces about 60% of the light. Modern lamps, especially T-8 linear fluorescent lamps (LFLs) are good at producing very high light quality with acceptable energy efficiency over an extensive lifetime, and compact fluorescent lamps (CFLs) are not far behind. However, even the best of today's T-8 LFLs convert only about 28% of consumed power into visible radiation. Mostly, this inefficiency is attributed to electrode losses (~16%), unwanted infrared emissions (~37%) and other discharge

column loses (~18%) including small amounts of ultraviolet emission. Grant applications are sought to develop technology to reduce these losses and thereby increase fluorescent lamp efficiency. Two selected opportunities, involving (1) new phosphor technology and (2) methods to eliminate mercury, are described in the paragraphs that follow, but other approaches for improving the performance of fluorescent lamps also would be of interest.

(1) Phosphors are essential for the energy efficient operation of low-pressure plasma discharge lighting in the form of either compact or linear fluorescent lamps. Inside the most efficient fluorescent lamps, both CFLs and all types of LFLs, almost 100% of the invisible, ultraviolet light is absorbed by the phosphors and re-emitted as long wavelength, visible light. Phosphor conversion efficiency is very close to one (i.e., one invisible UV photon produces one long wavelength, visible photon). The overall efficiency of this conversion is governed by various basic chemical processes, and, while the present embodiment of the technology is good, there is ample room for improvement. Physical effects on the macro-scale (such as particles size, lattice or host matching, crystal structure, and even methods of application) also can have a significant impact on lamp efficacy. Grant applications are sought to advance the state-of-the-art in phosphor technology for general illumination applications by developing novel conversion schemes that increase long wavelength photonic emissions. Areas of interest include, but are not limited to: Quantum Splitting Phosphors, a leading candidate for increasing the performance of lamps using phosphors, which has yet failed to reach commercialization; molecular effects including nanoscale properties; novel macro-scale effects such as unusual phosphor material structures or different manufacturing methods; and numerical modeling of novel energy conversion processes.

(2) All fluorescent lamps currently manufactured for sale in the United States contain various amounts of mercury. This small dose of mercury provides critical performance attributes that enable practical products like CFLs and LFLs to enjoy remarkable market penetration. Energy efficient attributes like lamp efficacy and cold starting are among the most important, but other practical attributes include color rendering, lamp to lamp consistency, output uniformity over life, and service lifetime. Succinctly stated, mercury makes conventional fluorescent lights work; without it, these important lamps would not be nearly as useful and energy efficient. However, some regulators worldwide have begun to phase out the mercury contained in lighting products, either directly by limiting disposal options or by requiring recycling of spent lamps. Although considerable research has been expended towards the goal of eliminating mercury altogether from fluorescent lighting products, designs for mercury-free fluorescent lamps have failed to reach the efficiency and performance levels of existing products and a significant technical challenge remains. Therefore, grant applications are sought for alternative lamp designs that do not depend upon mercury for efficient operation, and therefore do not contain any mercury at all. The mercury-free solutions required under this subtopic should have a form factor compatible with conventional fluorescent lamps or A-line lamps. Different power supplies or ballasts may be required but existing performance attributes must be maintained or exceeded. Life cycle costs must be comparable to existing CFL and LFL lamp products and should provide performance consistent with the goals of ENERGY STAR® lighting specifications.

c. Novel Solid State Lighting Structures—Light emitting diodes (LEDs) based upon, traditional III-V semiconductor materials and substrates are being developed to meet expanding demands in numerous markets including general illumination. However, for general illumination applications (those that require high color quality, broad spectrum, bright white light), the prospects for energy efficient solutions based on existing III-Nitride semiconductor technology (which uses near UV or blue monochrome light, down-converted with a yellow phosphor) appears to be constrained to less than 90 Lumens per Watt (LPW). Therefore, grant applications are sought to develop novel materials systems and structures that are fundamentally different than currently manufactured III-Nitride semiconductor systems and that promise performance in excess of 90 LPW. These novel solutions must be capable of eventually being commercially manufactured at a cost of $2.00 per 1000 lumens or less. For organic devices which are inherently less complex and costly to produce, certain pathways have already been demonstrated which may provide practical solutions for efficient white light production. However, there may be other, even more efficient materials systems solutions that, when combined with novel device architectures, may be even more attractive for general illumination. Alternative device configurations or hybrid structures that take advantage of efficient phosphor performance are of interest as are novel combinations of organic dyes and dopants that may shift spectral outputs to more desirable regimes. Approaches that represent incremental

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increases in III-Nitride semiconductor device performance are not of interest and will be declined.

In addition, configurations of existing semiconductor light producing devices may not be optimum for general illumination applications. External quantum efficiencies may be low and other geometric optical limitations may impose performance constraints that limit overall device efficiency. For example, the optical efficiency of today's white light devices can be as low as 10%. In order to maximize energy efficiencies, solid state lighting products of the future will extract at least 90% of the visible light produced. Therefore, grants applications are sought o develop alternative geometrical designs, matrices, or arrays of existing device designs that can overcome certain physical limitations, including heat dissipation and low optical efficiency, leading to novel device designs that promise device efficiencies in excess of 60%.

d. "Off-Grid" Solid State Lighting Devices—Solid state lighting (SSL) devices have evolved rapidly over the past several years to a point where certain monochrome or single color applications like traffic control lights and emergency lighting can incorporate them to reduce energy consumption while simultaneously providing superior performance over a long lifetime. Many industry experts believe that it is unlikely that there are many more near-term markets for monochrome illumination in general lighting (i.e., replacing incandescent lamps) until high brightness, inexpensive, high color quality, SSL sources are fully developed. Nevertheless, important energy conserving applications may exist for low power, small devices in selected small or niche markets where high spectral content white light is unnecessary. Furthermore, if these devices were powered by sunlight using existing solar voltaic and existing battery technologies, instant energy conservation could be realized because these devices could be removed from the power grid. Once they are off the power grid, their security would increase as they can be designed to operate for a specified period of time completely independent of the status of electricity service.

Grant applications are sought to develop novel designs for practical devices that can use commercial off-the-shelf technology for the SSL source, photovoltaic collection system, batteries, and controls. Grant applications must describe the subject market, its size, and the likelihood of market penetration. The subject devices should be cost competitive with the designs they replace, and life cycle cost comparisons must also be provided. For new applications where no conventional lighting system is used, societal benefits should be described. Examples of the kinds of devices sought include but are not limited to: remote lighting and signage, architectural illumination, security lighting, landscape lighting, marine applications, and portable illumination.

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37. ENERGY EFFICIENT MEMBRANES

Separation technologies 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 today 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.

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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, research is needed to develop new, more effective membrane materials and innovative ways to incorporate membranes in industrial processes. Grant applications must address the potential public benefits that the proposed technology would provide from reduced energy consumption and from the reduction in one or more of the following: materials consumption, water consumption, and toxic and pollutants dispersion. Grant applications should also include a plan for introducing the new technology into the manufacturing sector, in order to access capabilities for widespread technology dissemination. **Grant applications are sought only in the following subtopics:**

a. Membrane Materials with Improved Properties—Grant applications are sought to develop lower cost inorganic, organic, composite, and ceramic membrane materials in order to improve one or more of the following properties: (1) increased surface area per unit volume, (2) higher temperature operation (e.g., by using ceramic or metal membrane materials), and (3) suitability for separating hydrophilic compounds in dilute aqueous streams. Particular membrane materials of interest include nano-composites, mixed organic/inorganic composites, and chemically inert materials. Particular processes/systems of interest include membranes for the separation of biobased products, membranes for hydrogen separation and purification, and membranes for industrial applications. Grant applications must be targeted toward the development of specific membrane materials for carefully defined commercial applications; efforts focused on generalized membrane material research are not of interest and will be declined.

b. Membranes for Separations of Biobased Products—Grant applications are sought to develop membrane technology to enhance the production of large volume, value-added chemical products using biomass feedstocks. These processes may use either enzymatic or chemical catalysis, and may be conducted in either aqueous reaction media or organic solvents. Grant applications must demonstrate a clear connection to a crop-based feedstock and a large volume chemical product (one that would be manufactured at greater than 500 million pounds). Of particular interest are (1) novel membrane processes that use reactive separation technology, which combines the reactive transformation with the separation; and (2) novel membrane materials with higher flux or selectivity, and with improved chemical and thermal membrane stability.

c. Hydrogen Production—Hydrogen can be produced from coal, natural gas, biomass, and biomass derivatives through the use of gasification, pyrolysis, reforming and shift technologies. In all cases, a hydrogen rich producer gas or syngas results, from which the hydrogen must be separated and purified. The most common approach today involves the use of pressure swing adsorption (PSA) technology. The use of membranes holds the promise of reducing cost by combining the separation and purification with the shift reaction in a reactive separation operation. Therefore, grant applications are sought to develop improved hydrogen membrane separation and purification technology for use in the production of hydrogen; the focus of the research should be on low cost, high flux rate, durable membranes systems that can be integrated with the shift reaction. Membranes of interest include ceramic ionic transport membranes, micro-porous membranes, and palladium based membranes. Such membranes could be used for a wide range of production capacities, from large central production facilities (50,000-300,000 kgs/day of hydrogen) to small-distributed production units (50-1000 kgs/day of hydrogen).

d. Industrial Membrane Process Systems—Grant applications are sought to enhance the separation capabilities of membranes used in industrial process streams. Proposed research should be aimed at developing and commercializing innovative membrane systems, using new or currently existing membranes, that can be robust when integrated within real-world processes (e.g. inert gas removal, isomer separation, aromatic/non-aromatic separations, sulfur removal, removal of trace metals). Grant applications should seek to 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) manufacturing technologies that would reduce the cost of membrane modules, (3) anti-fouling and anti-flux schemes to improve the long-term operability of membrane systems, and (4) methods to regenerate membrane performance and lower membrane maintenance costs. The integration of membranes with other technologies to address specific process issues

would also be of interest. Grant applications should also include a process evaluation and an economic analysis along with the R&D effort.

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38. MATERIALS FOR INDUSTRIAL ENERGY SYSTEMS

Efficiency gains in industrial processes and distributed energy systems will not only result from the development of higher temperature, more thermodynamically efficient processes, but also from the development of new materials. Affordable metals, ceramics, or composites with improved high temperature properties are needed to improve productivity, reduce equipment size, and lower energy use per unit of production. These new materials can enable more efficient thermal process heating systems, improved up-time, increased yield, and more stable operations. Many economic sectors (including the aluminum, chemical, glass, forest products, metalcasting, steel, and mining industries; supporting industries; and the distributed energy industry) can benefit from new materials. Some of the unit processes where new materials advances are required include fluid heating, melting, sintering, heat-treating, pre-heating, calcining, combustion, and distributed power generation. **Grant applications are sought only in the following subtopics:**

a. Refractories and Insulation—New refractories and high temperature insulation materials are critical to many industrial processes and can directly impact the energy

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efficiency of manufacturing processes. In the steel industry, for example, refractories that can withstand higher heating rates and that have improved mechanical and thermal shock properties (e.g., for applications such as ladles, blast furnaces, and protective coverings) can lead to significant energy benefits. In the glass industry, crown and side wall refractories with improved corrosion resistance to molten glass and volatiles, as well as improved high temperature properties, can lead to higher thermal efficiencies in two ways: first, by enabling the energy efficient oxyfuel firing process to be utilized more effectively, and, second, by improving yield due to decreased glass contamination from refractory inclusions and corrosion effects. In the aluminum industry, refractories with improved corrosion resistance to cryolite, and with high thermal insulation, erosion resistance, and corrosion resistance would result in significant energy benefits. Grant applications are sought to develop new refractory materials that will provide improved thermal resistance, increased corrosion resistance, high thermal shock, and high temperature strength. Of particular interest are approaches that address the development of preformed shapes, coatings, or surface modifications.

In addition, materials with low thermal conductivity would have significant benefits. These materials include fibers and porous materials, along with low-density materials coupled with higher density refractories on exposed surfaces. Therefore, grant applications are also sought to develop (1) low thermal conductivity, high temperature materials with increased their service life at high temperatures and under corrosive conditions, and (2) techniques for bonding fibrous or porous materials to a dense surface refractory layer.

b. Metallic Alloys and Composites—Metallic alloys play very significant roles throughout industrial and distributed power industries. Grant applications are sought to develop: (1) improved creep rupture properties, for example, by using nanophase strengthening mechanisms for bulk alloys, and developing new materials/process relationships to enable more accurate design for long term service; (2) processing and joining techniques for wrought alloys/composites in order to increase the upper use temperature limits of current alloys by 100 C, or to beyond 1200 C; (3) new or improved performance materials for furnaces, boilers, and other process heating applications; (4) alloys for increased resistance to chemically aggressive environments, especially with regard to sulfidation; and (5) advanced materials for waste heat recovery systems for use in dirty, contaminated, or corrosive waste streams in industries where equipment fouling is a serious problem.

c. Ceramics, Composites, and Coatings—Advances in ceramics, composites, and coatings can significantly improve the thermal efficiencies of many industrial and distributed power generation processes, including heat generation systems, heat transfer operations, heat containment, and heat recovery. In the area of heat generation, grant applications are sought to develop new ceramics, composites, or coatings for flame stabilizers with increased oxidation resistance for longer life; nozzles with improved coking and carburization resistance and improved high temperature oxidation behavior; and improved wear and erosion resistance for many process system components. Regarding heat transfer operations, grant applications are sought for ceramic/composite tubes that would enable new melting and process heating technologies, and for materials developments that would greatly decrease the corrosion of large metallic components. Lastly, grant applications are sought for materials that would enable the use of new process sensing technologies (e.g., probes and sensors that can be used within a furnace or boiler).

d. Novel Heat Exchangers—Cooling, heating, and power (CHP) integration is an essential market for thermally activated technologies. One important example of CHP is the heat recovery/transfer from microturbine exhaust gases (500F to 600 °F) into hot water. Current technology uses conventional fin-tube heat exchangers and requires significant volume (e.g., 34 ft^3, with floor space of 12 ft^2 and weight of 820 pounds). Grant applications are sought to design and develop novel materials and enhanced surfaces (including ceramics, polymer based materials, coatings, membranes, and fluids) for heat exchangers and accompanying systems (e.g., micro-channel, rotating systems, etc.) The grant application must address how the technology will contribute to reductions in overall system size, weight, and cost; and improved reliability.

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39. NEW ENERGY SOURCES

To meet national energy needs, diversify energy supplies, reduce security and reliability risks, and reduce environmental impacts, there is a need to develop new clean, domestic energy supplies. Important options include new sources of electricity, clean sources of hydrogen, and low cost sources of thermal energy for loads such as residential water heating. This topic addresses important facets of each of these new energy sources. **Grant applications are sought only in the following subtopics:**

a. Materials and Components for Solar Energy Systems—Silicon accounts for most photovoltaic (PV) modules manufactured in the world, despite the promise of alternative technologies, such as thin-film solar cells that use other materials. As the popularity of PV grows and markets expand, larger, lower-cost sources of silicon will be required to satisfy future PV production. Historically, off-spec electronics grade polycrystalline silicon, in the form of chunks and beads, has been the source of growth feedstock for crystalline silicon solar cells. This off-spec material, sometimes referred to as "solar grade" silicon, has a sufficiently low concentration of mobile ions, making it suitable for commercial solar cells with efficiencies of at least 13%. Grant applications are sought to develop novel, low-cost processes, amenable to large-scale production environments, for the production of "solar grade" crystalline silicon feedstock material. Such processes must be able to deliver low-mobile-ion material at costs of $10 to $20 per kilogram with production rates as low as several thousand metric tons per year. Of particular interest is the ability to deliver material with low boron and phosphorus concentrations, important attributes for inexpensive manufacturing of efficient solar cells.

The high initial cost of solar water heating systems could be reduced by using polymer materials instead of traditional aluminum, copper, and glass. Also, the simplification of components and subsystems, as well as their design for multiple uses, offers the prospect of reduced cost in manufacturing, fabrication, and installation. Two industry teams are currently developing prototype polymer solar water systems based on the integral collector storage (ICS) design (passive, with storage in the collector and no tank), focusing primarily on collectors and heat exchangers. Because ICS systems are suitable only in non-freezing climates, development activities also include polymer solar water

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heaters based on active, freeze-protected system designs. Grant applications are sought for the conceptualization and design of innovative approaches, materials, and components for low-cost solar water heaters. Approaches of interest could involve the entire water heating systems or be confined to components and sub-systems that would be used in complete solar systems. Approaches need not be restricted to polymers, metals, or any single type of material, but could employ any combination thereof. Of particular interest are approaches that include the downsizing of components or subsystems without any degradation in performance.

b. Low Head Hydropower Systems—Current ongoing studies indicate that, in the continental United States, there is enough low head hydropower resources to provide 15,000 to 20,000 MW of electrical capacity. However, conventional hydropower technology is focused on large hydropower sites and does not apply well to the low head hydropower resource. Grant applications are sought for the development and implementation of innovative, cost effective, and environmentally acceptable concepts for low head hydropower energy systems for the production of electricity. The overall project must pursue a working demonstration as proof of concept. It is anticipated that a number of design approaches may meet these objectives, leading to worldwide marketability and application for the technology.

c. Power Converters for Diverse Applications—Power converters that convert variable voltage and frequency, AC and DC power to AC power (50/60 Hz) are needed for a variety of applications (e.g. wind, fuel cells, photovoltaic systems, etc.). Because much of the same "core" inverter technology can be utilized in different applications, a modular design approach would allow the multiple applications to benefit from economies of scale, reducing costs for all users. In this approach, the core inverter would include a power conversion section, a digital signal processor (DSP) based controller, minimal output filtering, and packaging; additional modules, (e.g., isolation, grid-tie, and additional filtering for lower total harmonic distortion) could be connected to the system on an "as needed" basis, facilitating plug-n-play implementation. Grant applications are sought for the development of the core power converter as described above. Because of the diverse applications, size, weight, and compatibility are very important criteria for consideration. An effective and practical power range/capability should be proposed, consistent with the intended application. For example, a small wind turbine should have a pow range on the order of 100 watts to 30 kilowatts. A nee also exists for a micro-inverter that could be integrate into a PV panel (AC PV building block concept) f roof-top mounting or into small PV-powered syste mounted on buildings (windows, walls, frames, etc. this micro-inverter should have a power capacity in t range of watts.

d. Hydrogen Production via Electrolysis Photovoltaic and Wind Systems—A great deal research into clean energy, especially for t replacement of fossil fuels in automobiles, has tak place on an international scale. One of the leadi technologies that has emerged is hydrogen, both f direct utilization with a modified carburetor and, mo recently, in non-combustion fuel cells that will genera electricity. One of the common ways to produ hydrogen is by electrolysis of water (H_2O). A relative low voltage applied to water causes water molecules separate into hydrogen and oxygen, which can then gathered and stored. By using solar or wind energy power the electrolysis generators, we can, in effect, sto the energy from these intermittent resources for u whenever it is desired. To date, only very sm experimental projects have been assembled using so power for electrolysis generators.

Grant applications are sought to develop effecti distributed (small for residential and large for centr station collection), low-cost, hydrogen producti systems using electrolysis with electricity supplied fr solar photovoltaics (PV) or wind energy syste Approaches should emphasize electrolysis units ma from very low cost materials, and ranging in size from 50 kW for smaller applications up to 200 kW and abo for larger or scaled-up systems. Capital costs should exceed $300/kW and a 60% electricity-to-hydrog efficiency should be provided. Electrochemi compression technologies to reach pressures from 2 5000 psi are encouraged. In order to further impr efficiency and lower capital costs, the electrolysis u should be amenable to integration with other syst components, such as power conditioning and storage.

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40. SENSORS AND CONTROLS

Robust, integrated measurement devices linked to intelligent control systems will enable the U.S. to use resources more efficiently and improve product quality. Through constant process monitoring and adjustment of parameters, these systems can reduce energy use and labor, minimize waste and pollution, and boost productivity. **Grant applications are sought only in the following subtopics:**

a. Real-time Measurement of Biomass Yield and Moisture Content—The ability to measure instantaneous yield and moisture content contributes significantly to efficient harvesting and down-stream processing of biomass. Instantaneous biomass yield, defined as the rate of dry matter throughput in a harvesting operation, is a function of the size and speed of harvesting equipment and the amount of biomass available for harvest – instruments for yield monitoring have been integrated in modern precision grain harvesting systems. Moisture content is defined as the ratio of the mass of water removed from biomass to the mass of dry matter (based on the oven method reference for moisture content, where moisture is completely removed from biomass using heat) – on-line moisture controllers have been perfected for grain storage and merchandising.

Yield and moisture content measuring instruments would be equally valuable to biomass handling operations if the measurements could be made in real time. In this case, the critical data on yield and moisture content could be used to maximize the performance of equipment in the field, for moisture adjustment (wet or dry processing), and for storage management. However, the low commercial value of biomass and the apparent non-uniformity in physical properties are among the barriers that have prevented the development of real-time moisture and yield monitors for biomass. Grant applications are sought for methods and instruments to measure moisture content and/or yield of biomass in real-time. Proposed systems may operate at one or several points along the supply chain: collection, baling, storing, preprocessing, and delivery point. Priority will be given to measurement techniques that are low cost, robust, and provide traceable performance.

b. Boiler and Furnace Sensors and Controls—In boilers and furnaces, sensors are used to measure the chemical and physical properties of both the material being processed and the combustion process itself. This

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information is then fed into control systems that make appropriate adjustments to optimize the combustion process. Grant applications are sought to develop innovative sensor and control technologies that provide new insights into controlling furnace and boiler systems and improving their efficiency. Approaches of interest include developing: (1) non-intrusive sensors based on optical methods; (2) self-learning and self-teaching smart control systems; (3) real-time sensors for measuring combustion phenomena; (4) sensors and control systems capable of measuring and controlling multiple emissions; and (5) low cost systems for measuring combustion energy efficiency performance including instantaneous energy consumption/efficiency and energy/fuel use and efficiency per unit of production.

c. Harvesting Power for Ubiquitous Wireless Sensing—In the near future, low cost, wireless sensor systems are expected to be everywhere: in buildings, in cars and on the production lines that build them, on other industrial production lines, and on power generation systems of all types. Their use will enable better measurement, better control, better operation, and lower energy consumption in numerous systems that we encounter every day. However, these wireless sensors and their transmitters will need power sources that last as long as the sensing application itself. While some batteries have long lives, the most obvious approach for powering these wireless sensors is to scavenge or harvest power from the sensor's operating environment. Therefore, grant applications are sought to develop this power harvesting technology, so that wireless sensors can be self-powered throughout their productive lives. The advent of ultra-low-power microelectronic designs should decrease the power requirements for these wireless sensors, rendering them completely autonomous if used with the type of creative power harvesting technologies sought here. Possible sources of power include thermal gradients, vibration, airflow, water flow, and solar energy, to name a few. Of course, there may be times (such as during start-up when the source of scavenged power may not even exist) when back-up power from a long lasting power source such as a battery may be required.

d. Integrated Sensor and Data Analysis Tools for Complex Mixtures—There is a widespread need for robust, low-cost integrated sensing and control technology for complex mixtures of chemicals. Chemical mixtures are found virtually everywhere, occurring routinely in biomass, building materials, reformer fuels, polymers used in wind turbines, and in the chemical and petrochemical industries. Improving the control of processes containing chemical mixtures would reduce raw material consumption and waste generation, decrease energy use and environmental emissions, and increase America's competitiveness. Improved chemical sensors also could be used to monitor specific components for indoor air quality and emissions from alternatively fueled vehicles. There have been significant advances in the development of small, relatively inexpensive chemical measurement devices (e.g., spectroscopy and chromatography) and in the development of data analysis tools (e.g., neural networks, multivariate techniques) capable of very rapidly analyzing large, complex data sets. Although these technologies have been used to characterize complex mixtures in the laboratory, development for the "real world" environment has progressed slowly. Therefore, grant applications are sought to develop systems that integrate new chemical analysis tools with advanced data analysis for the characterization of complex mixtures in real world settings.

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41. INNOVATIVE WASTE HEAT RECOVERY

Many industrial processes generate large amounts of waste energy that simply pass out of plant stacks and into the atmosphere or are otherwise lost. Most industrial waste heat streams are liquid, gaseous, or a combination of the two and have temperatures from slightly above ambient to over 2000°F. Stack exhaust losses are inherent in all fuel-fired processes and increase with the exhaust temperature and the amount of excess air the exhaust contains. At stack gas temperatures greater than 1000°F, the heat going up the stack is likely to be the single biggest loss in the process. Above 1800°F, stack losses will consume at least half of the total fuel input to the process. Yet, the energy that is recovered from waste heat streams could displace part or all of the energy input needs for a unit operation within a plant. Therefore, waste heat recovery offers a great opportunity to productively use this energy, reducing overall plant energy consumption and greenhouse gas emissions.

Waste heat recovery methods used with industrial process heating operations intercept the waste gases before they leave the process, extract some of the heat they contain, and recycle that heat back to the process. Common methods of recovering heat include direct heat recovery to the process, recuperators, regenerators, and waste heat boilers. Unfortunately, the economic benefits of waste heat recovery do not justify the cost of these systems in every application. For example, heat recovery from lower temperature waste streams (e.g., hot water or low-temperature flue gas) is thermodynamically limited. Equipment fouling, occurring during the handling of "dirty" waste streams, is another barrier to

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more widespread use of heat recovery systems. Innovative, affordable waste heat recovery methods that are ultra-efficient, are applicable to low-temperature streams, or are suitable for use with corrosive or "dirty" wastes could expand the number of viable applications of waste heat recovery, as well as improve the performance of existing applications. The focus of this topic is on the development of innovative waste heat recovery processes and techniques that are more efficient than conventional methods yet are still cost-effective, and those applicable to waste streams from which heat cannot easily be recovered with conventional methods. **Grant applications are sought only in the following subtopics:**

a. Low-Temperature Waste Heat Recovery Methods—A large amount of energy in the form of medium- to low-temperature gases or low-temperature liquids (less than about 250°F) is released from process heating equipment, and much of this energy is wasted. Grant applications are sought to develop technology for the additional processing of these waste streams before they are discharged into the environment. Approaches of interest include: (1) developing revolutionary process schemes, system designs, and equipment to allow economic recovery and reuse of the energy in these streams; (2) developing innovative technologies to economically upgrade low-temperature waste heat to useable process heat; and (3) developing technologies that can capture plant emissions and recover their fuel content.

b. Conversion of Low Temperature Exhaust Waste Heat—Grant applications are being sought for the design and development of technologies that are able to make use of the low temperature waste heat generated by prime movers such as micro-turbines, IC engines, fuel cells and other electricity producing technologies. The energy content of the waste heat must be high enough to be able to operate equipment such as chillers, refrigeration applications, heat amplifiers, dehumidifiers, heat pumps for hot water, turbine inlet air cooling and other similar devices.

c. Conversion of Low Temperature Waste Heat into Power—he steam-Rankine cycle is the principle method used for producing electric power from high temperature fluid streams. For the conversion of low temperature heat into power, the steam-Rankine cycle may be a possibility, along with other known power cycles, such as organic-Rankine. Grant applications are sought to design and develop power-cycle technologies that can utilize low-temperature (800 degrees F or lower) waste heat streams.

d. Small to Medium Air-Cooled Commercial Chillers—All existing commercial chillers, whether using waste heat, steam or natural gas, are water-cooled (i.e., they must be connected to cooling towers which evaporate water into the atmosphere to aid in cooling). This requirement generally limits the market to large commercial-sized units (150 tons or larger), because of the maintenance requirements for the cooling towers. Additionally, such units consume water for cooling, limiting their application in arid regions of the U.S. No suitable small-to-medium size (15 tons to 200 tons) air-cooled absorption chillers are commercially available for these U.S. climates. A small number of prototype air-cooled absorption chillers have been developed in Japan, but they use "hardware" technology that is not suited to the hotter temperatures experienced in most locations in the United States. Although developed to work with natural gas firing, these prototype air-cooled absorption chillers would also be suited to use waste heat as the fuel. Therefore, grant applications are being sought to design and develop waste-heat-driven, small-to-medium size commercial air-cooled absorption chillers, suitable for U.S. markets.

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PROGRAM AREA OVERVIEW
FOSSIL ENERGY

http://www.fe.doe.gov

Fossil energy plays a key role in our nation's prosperity, and it is important that we secure an adequate energy supply from our coal, natural gas, and oil resources. However, national complacency, derived from low-cost imported oil, has allowed petroleum imports to increase to alarming levels. 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, heating, 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 deleterious effects on the environment. 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. In addition, it is prudent to consider ways to reduce carbon dioxide and other greenhouse gases that are generated by the combustion of fossil fuels, to investigate carbon sequestration in geological and other systems, to consider hydrogen as alternate fuel, and to mitigate impacts on water resources. Advanced technology development in materials to assure compatibility with advances in power systems, will be needed for these challenges - as well as innovations in measurements, sensors, monitors, 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 reserves and through better infrastructure.

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

42. MEASUREMENT AND TECHNOLOGY FOR GASIFICATION

To sustain our economic growth, we need to utilize our most abundant fossil energy resource, coal, in an efficient and environmentally responsible manner. 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 costs. Gasification is a key technology for many energy related needs of the future, including clean production of electric power, hydrogen for the new "hydrogen economy," production of industrial chemicals or refined fuels with reduced impact on water resources, solid waste disposal, and capture of carbon dioxide (CO_2) generated in the use of fossil fuels. To meet the demands of the Hydrogen Initiative, the requirements for fuel cell and advanced turbine power units, and the increasingly stringent environmental regulations, the synthesis gas produced by gasification

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will need to be cleaned to tighter specifications. At the same time, gasification and gas cleanup processes will need to have reduced costs, improved reliability, and the ability to be readily integrated for increased efficiency. These improvements will enable the integration of advanced concepts for high-efficiency power generation and pollution control into a class of fuel-flexible facilities capable of operating with near zero environmental emissions. This topic seeks to develop key support technologies and measurement techniques for coal gasifiers. **Grant applications are sought only in the following subtopics:**

a. Advanced Refractory Systems for Gasification Systems—Refractory liners in high temperature slagging gasifiers are known to undergo significant deterioration over a relatively short period of time, requiring considerable maintenance. Depending upon the operating temperature of the gasifier, the plant size, and the feedstock, refractory liners last only 6-18 months and cost over $1 million in materials, manpower, and lost revenues to replace. Therefore grant applications are sought to develop advanced refractory systems or new materials with an expected useful life of three or more years and the ability to withstand multiple feed stocks such as coal, biomass, and petroleum coke. Of particular interest are materials that cost 50% or less than current materials and materials that contain no chromium.

b. On-Line Flow and Composition Measurements for Gasification Systems—The ability to measure, control, and quickly respond to fluctuations in flow quantity and composition of the feed streams to gasifiers, as well as in the synthesis gas product stream, can be crucial for maintaining performance levels at design standards and for keeping on-stream gasifier production at high capacity. Real-time, on-stream measurements are likely to be helpful in identifying system upsets and generating responses to protect downstream equipment. Grant applications are sought to develop robust, real-time, on-line measurement and control systems for the following gasifier flows:

(1) The feeding of abrasive and eroding solids into gasifiers across pressure barriers up to 1000 psi. The gasifier feeds are typically water slurries with loadings of 50-70% solids or pneumatically-fed dry pulverized solids. The feed may contain coal, pet coke, coal-pet coke mixtures (typically 50% for each), water as the slurry agent, or biomass (typically 10 -20%). On-line measurements of feed quantities and composition should address such attributes as particle size distribution, particle loading, changes in coal/pet coke/biomass composition, and the amount of water.

(2) Product synthesis gas streams, laden with aggressive particulates, at high temperature (up to 2500 °F) and high pressure (up to 1000 psi). The synthesis gas product will typically contain bulk constituents (CO, CO_2, H_2, H_2O, CH_4), major contaminants (H_2S, COS, NH_3, Cl), and trace contaminants (Hg, As, Se, V, Ni). On-line measurement of any or all of these constituents at gasifier exit conditions would enable more direct control of gasifier operation.

c. Gasifier Injectors—In the operation of many types of gasifiers, the feed enters the gasifier vessel through an injector with small orifices, which become exposed to the high temperature, high pressure, corrosive, and reducing conditions of the gasifier. The injector orifices are further subjected to melted mineral matter that becomes slag on cooling. In this environment, the orifices and injector devices become non-functional and need to be replaced, causing down-time in gasifier operation. Grant applications are sought to develop devices and materials that can extend the useful lifetime and reduce the replacement costs of these injectors.

d. Warm, Multi-Contaminant Gas Cleanup—Advanced gasification systems will be needed to provide synthesis gas feed for advanced, combined cycle power plants; for separation systems for hydrogen production or for separating CO_2 for sequestration purposes; or for chemical conversion plants. All of these advanced applications will require that any sulfur-containing species, as well as other contaminants, be reduced to parts-per-billion (ppb) levels. For acid-gas removal, such as sulfur, technologies that are either currently available or under development include: (1) low-temperature or refrigerated solvent-based scrubbing systems using amines, such as MDEA, or methanol (Rectisol, Selexol, Sulfinol), or (2) high temperature sorbents (as yet not demonstrated at commercial scale). However, these gas cleaning processes operate at temperatures that are either below or above the temperature of the downstream processing operations (say, for gas turbine fuel systems and catalytic synthesis processes), which are in the range of 300 to 700°F. These temperature differences lead to energy efficiencies: the low temperature clean-up processes require temperature reductions to below 100°F and then reheating to downstream process requirements; the high temperature sorbent systems operate at 1000°F, requiring unnecessary gas stream severity. Therefore, grant applications are sought for desulfurization systems that

can be matched to the elevated temperature and pressure conditions of gasification processes (i.e., temperatures in the range of 300-700°F and pressures in the range 300-1000 psi) and that can be integrated with the warm-gas cleanup of other contaminants (trace components and heavy metals), which must be reduced to negligible levels. Contaminants of interest include mercury, arsenic, selenium, cadmium, vanadium, and nickel. Ammonia, halides, and other gaseous contaminants also are of interest. Cleanup technologies that address multi-constituent cleanup, as opposed to individual technologies for individual contaminants, and processes within the 500°F to 700°F temperature window, are strongly preferred. A good reference discussion of both acid gas removal (sulfur, in particular) and mercury removal can be found on the National Energy Technology Laboratory Gasification Technologies website at the following addresses: http://www.netl.doe.gov/coalpower/gasification/pubs/pdf/SFA%20Pacific_Process%20Screening%20Analysis_Dec%202002.pdf or http://www.netl.doe.gov/coalpower/gasification/pubs/pdf/MercuryRemoval%20Final.pdf

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43. COMBUSTION TECHNOLOGIES AND WATER RESOURCES

The DOE-sponsored Vision 21 program aims at the development of sophisticated technologies for combining power generation, fuel production, and the option of CO_2 sequestration into customizable packages that would offer higher net efficiencies than stand-alone technologies. These packages would be capable of providing low cost energy from coal or natural gas, while co-producing fuels and chemicals and reducing CO_2 emissions. In order to accomplish the Vision 21 program, novel technologies need to be conceptualized and developed, especially those with potentially lower costs or higher efficiencies. In particular, advances in combustion technologies are needed for the development of the envisioned power systems.

The first two subtopics are concerned with a new combustion technology, chemical looping combustion, that, until now, has been developed for gaseous fuels. Chemical looping is a process by which the combustion of a hydrocarbon occurs in two steps: in the first step, air is used to oxidize an oxygen carrier (e.g. Fe); in the second step, the carrier (e.g. Fe_2O_3) is used to oxidize a fuel (with the carrier reduced to its metal form). In this process the carrier is circulated in two separate reactors: a combustion step where the oxygen carrier reacts with the fuel, and an oxygen regeneration step in which the carrier is oxidized with air. An advantage of this process is that the CO_2 is emitted as a concentrated steam that is ready for subsequent sequestration.

The third subtopic seeks to develop a turbulent reactor for more efficient hydrogenation to produce high hydrogen fuels. Lastly, because power generation processes, as well as the mining for fuel, drains our water resources, the fourth subtopic aims at reducing the amount of water use and improving its quality in association with fossil energy processes. **Grants applications are sought only in the following subtopics:**

a. Development of Oxygen Carrier Particles for Chemical Looping Combustion of Solid Fuels— Although research and development on chemical looping combustion has been published in the literature since 1994, several problems have restricted its use to the combustion of gaseous fuels such as methane and natural gas. One of these problems is the lack of robust and effective oxygen carriers. Therefore, grant applications are sought to develop robust oxygen carrier particles suitable for chemical looping combustion of solid fuels.

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The oxygen carrier particles must: (1) provide high rates of reactivity for both reduction and oxidation processes; (2) possess superior mechanical, thermal, and sintering properties that can withstand the harsh environment without particle breakage, attrition, and sintering; (3) be capable of maintaining high reactivity after recycles; (4) be low cost and environmentally sound. Applications of chemical looping combustion that are directed toward power generation and co-production of other fuels and/or chemicals are of particular interest.

b. Innovative Methods for Chemical Looping Combustion of Solid Fuels—In addition to the need for more robust and effective oxygen carriers, the adaptation of the chemical looping process to the combustion of solid fuels presents other challenges. Technical difficulties include the separation of the oxygen carrier particles from fuel and ash particles, the possible interaction between the fuel ash and oxygen carriers, the lack of free oxygen for combusting solid fuel particles, and the combustion of unburnt carbon particles in the oxidizer due to the circulation of solid fuel particles from the reducing reactor to oxidizing reactor. Grant applications are sought to develop novel methods to address these technical issues that would arise during the combustion of solid fuels in the chemical looping process.

c. A Truly Turbulent Reactor for Hydrogenation Reactions—Hydrogenation reactions are becoming more attractive as demand grows for cleaner high hydrogen forms of some petroleum-based fuels such as ultra low sulfur diesel. At the same time, the development of a more efficient process for the direct liquefaction of coal remains a viable option, especially overseas where labor costs are lower than in the U.S. Both of these processes face the extreme difficulty of providing an efficient contact between the hydrogen gas and the fossil feed being treated. Calculations and practice have demonstrated that it is nearly impossible to disperse small bubbles of hydrogen in a hydro-carbonaceous slurry or fluid. The problem is that the low density of a hydrogen gas stream does not provide enough momentum to keep it dispersed. However, recent unpublished and incomplete data suggest that even simple mixers can promote and maintain hydrogen dispersion. In fact, the so-called in-line mixers, perhaps modified by innovative designs, may accomplish the necessary improvements. Grant applications are sought to design, fabricate, and test an improved hydrogenation reactor that may be in turbulent flow in order to disperse the hydrogen gas in the fossil feed and to confirm the expected high rates of conversion and product yields.

d. Water Usage in Electric Power Production—Power generated from fossil fuels, especially coal, is dependent on water. On average, approximately 30 gallons of water are required for each kWh of power produced from coal. Thermoelectric power production uses approximately 132,000 Mgal/day of fresh water, second only to irrigation. Mining also uses a large amount of water, estimated at 3,770 Mgal/day, impacting both surface and ground water. In power generation, the largest single use of water is for cooling the low-pressure steam from the turbine. Air has been considered as an alternative, but air-cooled systems (sometimes referred to as dry systems) can have associated capital-cost and energy-inefficiency penalties, particularly in retrofit applications. Grant applications are sought to develop novel concepts and technology to reduce both the amount of water used and the potential impact on water quality, and must be directed toward one following areas of interest: (1) reducing water used in power generation, and (2) water quality improvements in power generation.

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44. MATERIALS FOR ADVANCED POWER SYSTEMS

New materials, ideas, and concepts are required to significantly improve performance and reduce the costs of existing fossil systems or to enable the development of new systems and capabilities. The Fossil Energy Materials Program conducts research and development on high-performance materials for longer-term fossil energy applications, including high-temperature/high-pressure heat exchangers, hot gas filtration systems for removing particulate matter formed during coal combustion and coal gasification, gas separations, high-temperature fuel cells, and advanced turbine systems. The program is concerned with operation in the hostile conditions created when fossil fuels are converted to energy. These conditions include high temperatures, elevated pressures, pressure oscillations, corrosive environments (reducing conditions, gaseous alkali), surface coating or fouling, and high particulate loading. **Grant applications are sought only in the following subtopics:**

a. Coatings for Coal-Fired Environments—In order to achieve higher operating temperatures in fossil energy systems, where sulfur and water vapor can cause severe oxidation problems, the corrosion resistance of Fe- and Ni-base alloys must be improved. In power generation applications, typical examples of surface damage include: (1) accelerated high-temperature fire-side corrosion associated with the presence of molten alkali-containing salts; (2) accelerated medium-temperature fire-side corrosion associated with the presence of a low oxygen activity environment and sulfur; and (3) steam-side oxidation of tubing, piping and valves in fossil fuel-fired boilers. Grant applications are sought to develop protective coatings and coating techniques for the Fe- and Ni-based alloys, and for nickel-based superalloys as well. The coatings must provide superior corrosion resistance in oxidizing, sulfidizing, carburizing, and water-containing environments. The protective coatings and coating techniques should be optimally designed as part of the overall power generation system, should be maintainable, and should be capable of non-intrusive evaluation to determine remaining life. To this end, model coatings should be fabricated for corrosion testing and diffusion studies in order to develop a comprehensive lifetime evaluation approach for the coatings. At least one ferritic and one austenitic alloy should be selected as substrate materials for study. The approach should provide sufficient data regarding lifetime performance in applicable environments.

b. Hydrogen Separation and Storage Materials—Hydrogen separation materials based on inorganic membranes and materials for hydrogen storage are critical supporting technologies for next generation power systems. Two types of inorganic membranes are being investigated for the recovery of hydrogen from coal gasification streams: porous membranes and dense membranes. These membrane types differ significantly in their microstructures, and, therefore, gas separation takes place by entirely different hydrogen diffusion mechanisms, as described below. Grant applications are sought to further the development of either or both types of these ceramic membranes for commercial hydrogen production. Proposed approaches must demonstrate that the hydrogen can be produced in large quantities and at high purity; therefore, both the permeation properties and the selectivity of the membranes must be well characterized and understood.

In porous membranes, hydrogen is transported through the pores as molecules and the process occurs readily. The separation membrane is usually made from silica and/or alumina supported by a highly porous metallic or ceramic layer. Zeolite membranes also fall in this category. Porous membranes are being designed to operate at temperatures in the range of 250-1000°C to be compatible with Integrated Gasfication Combined

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Cycles (IGCC). Currently, the maximum operating temperature for these membranes is about 500°C, although even at this temperature, there are concerns with stability in H_2O-containing atmospheres.

In dense membranes, hydrogen is transported in the solid phase as hydrogen ions (protons) or as hydrogen dissolved in the inorganic phase. Membranes with high protonic conductivity include such ceramics as doped $SrCeO_3$ and $BaCeO_3$, which also should have high electronic conductivity and low oxygen ionic conductivity. Membranes based on palladium are examples in which the hydrogen is transported as a solute in the inorganic phase. In principle, both types of dense membranes can produce very high purity hydrogen because only hydrogen is transported through the membrane. Along with high flux, the membranes should exhibit stability in environments typical of coal-derived gases.

Another critical need is the development of materials for hydrogen storage. These materials include alloys and intermetallics, sodium and lithium alanates, nanocubes, carbon nanotubes, or other emerging materials. Grant applications are sought to develop materials that provide high hydrogen storage density and stability at commercially relevant conditions of temperature and pressure. The materials to be investigated must be amenable to realistic processing conditions and to the likelihood of large-scale manufacturing.

c. Seals for Gas Separation Membrane Systems—Ceramic membranes, which have operating temperatures between 250 and 1000°C, are attracting increasing attention because of their technological importance in high temperature gas separation and membrane reactor processes. However, in order to fully exploit the unique properties of these advanced ceramics, the ceramic membranes must be sealed to a dense ceramic or a metal support structure. Commonly used seals are not suitable for these applications because their heat resistance is ineffective above 400°C. Therefore, grant applications are sought to develop inorganic materials with high melting points that can be used for sealing the ceramic membranes at high temperatures (greater than 600 °C). For good sealing results, the seals must be tailored to obtain suitable wettability, viscosity, chemical inertness, thermal expansibility, and bonding strength. The sealing of these ceramic membranes should achieve a success rate of nearly 100% if correct sealing procedures were adopted.

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45. GREENHOUSE AND HYDROGEN GAS RESEARCH

The environment is a major concern to the fossil energy program. As more and more emission issues become resolved, global warming and greenhouse gas emissions have moved up in importance. Global warming is a consequence of the heat-retaining property of gases such as carbon dioxide (CO_2), released to the atmosphere from the combustion of fossil fuels for power generation and from the natural decomposition of organic carbons such as fibers, tissues, leaves, and food. Because CO_2 is a heat opaque gas, radiation does not simply pass through it; rather, through various modes of vibration, some of the heat in the radiation is absorbed by CO_2 molecules. Other gases such as methane (CH_4) and nitrous oxide (N_2O) share this partial heat-retaining property. Together, they are known as greenhouse gases. The focus of this topic is on reducing the level of greenhouse gases. In addition, because the adoption of hydrogen as a fuel may help mitigate greenhouse gas emissions, this topic also addresses the extraction (or production) of hydrogen from natural gas. **Grant applications are sought only in the following subtopics:**

a. Amine Scrubbing of CO_2—Significant research and development is currently being pursued for new technologies to separate and capture CO_2 from both fuel and flue gas streams. Currently, the amine scrubbing process is the only commercially-available option for removing CO_2 from gas streams related to coal combustion in energy systems. Several amine compositions are commercially available for the process, including monoethylamine (MEA) and diethylamine (DEA). MEA is the most common as it is relatively inexpensive, highly reactive, and offers high capacity and high removal efficiency. However, MEA has a number of drawbacks, including its corrosivity and its reactivity with contaminants commonly found in the process stream (reference 1). In addition to the problems with MEA, the amine scrubbing process has significant costs, both capital and operating, due to the complexity of its systems (reference 2). Grant applications are sought to develop technology needed to address these shortcomings. Areas of interest include: (1) determining operational and practical issues related to feed stream gas composition and scale-up of aqueous scrubbing systems through non-site-specific design studies; (2) determining the effects of temperature, oxygen, sulfur oxides, nitrogen oxides (NO_x), hydrochloric acid, and ash on such process parameters as amine losses, corrosion, foaming, aerosols, and disposal of waste related to aqueous scrubbing; (3) determining methods or practices to minimize operational costs associated with flue gas desulfurization and amine loss, in particular; (4) determining system designs or operational practices to minimize steam usage and optimize the integration of the aqueous scrubbing system into the steam cycle; and (5) determine scale-up issues and cost to apply an aqueous scrubbing system at one or more actual industrial sites.

b. Post Combustion De-Carbonation—Coal-based power plants account for over 50% of electricity generation capacity in the U.S. Most of these plants use pulverized coal boilers to generate superheated steam for turbine applications. The flue gas stream contains carbon as CO_2, along with nitrogen and other minor components such as SO_2 and NO_x. It is desirable to sequester the CO_2 emission from these plants in order to reduce the buildup of greenhouse gases in the atmosphere. The first step is to produce a concentrated CO_2 stream ready for sequestration, since its concentration in the flue gas is only in the 10-15% range. Although some commercial technologies, which use chemical/physical solvents such as amines, are available for effecting CO_2 separation, these processes are both capital intensive and high in operating costs.

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Therefore, grant applications are sought to develop alternative technologies that can substantially lower the cost of CO_2 separation from the flue gas. Among the candidate technologies, some data has already been developed for membrane separations and solid adsorbents (reference 1). Grant applications should demonstrate familiarity with both current commercial technologies and ongoing work in new technology research, discuss how the presence of minor flue gas components would affect the new technologies, and account for the effect of flue gas conditions such as flow rate and temperature.

c. Non-Carbon Dioxide (Non-CO_2) Greenhouse Gas Reduction—Until recently, efforts to understand and reduce the level of greenhouse gases have focused on carbon dioxide sequestration, more efficient use of carbon fuels, and lower carbon-content fuels. Recent publications by Hansen, et al., have shed new light on the importance of non-CO_2 contribution to greenhouse effects. Grant applications are sought to develop technology that could significantly reduce the escape to the atmosphere of two of these non-CO_2 gases: methane (CH_4) and nitrous oxide (N_2O). Areas of interest include the reduction of these emissions from oil and gas exploration and production, coal mines, landfills, refineries, rice cultivation, enteric fermentation, fertilizer utilization, manure, residue burning, biomass production and use, and other sources.

d. Conversion of Natural Gas to Hydrogen—U.S. demand for hydrogen is now about 9 million tons per year (reference 1) and is anticipated to greatly expand as the Nation moves toward a hydrogen economy. Currently, the principal uses of hydrogen include petroleum refining and manufacture of nitrogen fertilizers. As a primary hydrogen source, many refineries rely on the hydrogen that is a byproduct from naphtha catalytic reformers. Supplemental hydrogen, as well as hydrogen used in fertilizer and petrochemical manufacturing, is produced primarily from the catalytic steam reforming of natural gas. Natural gas, which has a favorable hydrogen to carbon ratio (4:1) compared to coal (0.7:1) or biomass (1:1), is the most affordable near term resource for producing large amounts of hydrogen. Current commercial technology (via SMR) produces hydrogen from methane at a cost of $5.54/MM Btu, with a feed natural gas price of $3.15/MM Btu. This figure does not include the costs of carbon sequestration, which is the major driving force toward a hydrogen economy. In order for hydrogen to become a viable fuel for motor vehicle use, the cost of hydrogen production must be reduced.

Current DOE and industry funded research is developing technology that will simplify the production of hydrogen from natural gas by combining two steps – air separation to produce oxygen and partial oxidation of natural gas to produce synthesis gas – into one, leading to lower costs and increased efficiencies. Also, membranes to separate hydrogen from hot synthesis gas are being developed. The goal is to reduce the cost of hydrogen production from natural gas by 25% over the next ten years. This is a considerable task, since, over a period of decades, the petroleum and chemical industries have optimized the current technology on an operating and capital cost basis.

Grant applications are sought to develop new, non-microbial, technologies for the production of hydrogen from natural gas. Areas of interest include catalysis (syngas and/or water-gas shift), membrane and other separation processes, and reactor systems. Hydrogen production processes that also enable the separation of carbon (as carbon dioxide or elemental carbon) are of particular interest. Cost effectiveness, compared to currently available hydrogen production technologies (references 2 and 3) must be demonstrated. The process must produce hydrogen at lower cost (capital and operating) and higher efficiency than steam reforming technology.

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46. SEQUESTRATION OF CARBON

The world is becoming increasingly concerned about the greenhouse effect, and CO_2 emission is a significant contributor to it. Hence, the permanent sequestration of CO_2 has become a major world wide goal. In the United States, geologic storage of CO_2 is expected to be an important element of any strategy implemented to reduce the emission of this greenhouse gas to the atmosphere. Other sequestration possibilities also need to be explored, for example in solid and in above-ground vegetation. In order to assure the safety and reliability of these sites to permanently store CO_2, it will be essential to verify and monitor such sequestration. **Grant applications are sought only in the following subtopics:**

a. Identifying Suitable CO_2 Storage Sites of Verifiable Integrity and Quantified Capacity—Storage sites for carbon dioxide must be identified and verified so that they will be available for use when needed. It also must be assured that the sites will not leak and that safe storage pressures can be determined. Both power plant operators and government oversight entities will require the means for screening and selecting these storage sites. Grant applications are sought to develop sophisticated tools to evaluate the suitability of potential storage sites such as saline aquifers, depleted oil and gas reservoirs, and unmined coal seams. The storage site parameters that require determination include multi-phase flow, potential leakage, ultimate storage capacity, and the dissolution of CO_2 in or its adsorption on various media which might be present (e.g., saline water, oil, or coal). An inventory of potential sites, along with the determination of pertinent attributes for each, could serve as a national register for carbon sequestration.

b. Sequestration of CO_2 in the Outer Layers of the Earth's Crust—Large volume locations for sequestering CO_2 have generally not been found. Underground disposal is appealing, but so far the only attractive possibilities are storage in depleted gas wells or storage in saline water wells. Unfortunately, these geologic features are few and far between. An alternative type of underground site must offer an opportunity for the chemical bonding of CO_2 to some material that is existent underground. One promising candidate would be a deposit of one or more of the mineral silicates – e.g., calcium silicate ($AlKSiO_3$) or magnesium silicate (Mg_2SiO_4,). The reaction of CO_2 with silicates of this type results in the conversion of the mineral into a insoluble carbonate and the precipitation of SiO_2, which drives the reaction to completion. The CO_2 would be thus permanently sequestered.

Grant applications are sought to develop alternative types of underground CO_2 sequestration. Initial tests

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should be conducted in a test mock-up or at qualifying terrestrial location for the above system, either for the one of the silicate systems described above or for an alternative and novel means of sequestration. In these systems, care must be taken to avoid injecting the CO_2 at an excessively high rate; otherwise, it could cumulate underground, leading to a sudden, large discharge of CO_2 with adverse health impacts to workers and/or passers-by. Therefore, the selected approach must include the ability to determine the maximum pressure for CO_2 delivery, in order to assure that the rate of injection of CO_2 into the selected area is limited to the rate at which the CO_2 reacts with the underground mineral.

c. Regenerable Processes for CO_2 Capture—Flue gas produced from fossil fuel combustion consists of, nominally, 15% CO_2 and 82% nitrogen, with the remainder mostly oxygen. This CO_2 concentration is far too low to be sequestered directly; therefore, the CO_2 must first be concentrated to over 90%, or near purity, in order to be sequestered economically by any sequestration methods. Currently, chemical solvent scrubbing processes, such as the monoethanolamine (MEA) process, are the most widely used CO_2 capture technologies. In the MEA process, the MEA aqueous solution absorbs CO_2 at 100°F or slightly higher, and when the CO_2-rich MEA solution is heated to approximately 250°F, the CO_2 gas is released in high purity. The MEA process is termed "regenerable" because the CO_2 is absorbed at low temperature and then released at a higher temperature. The regenerated, high purity CO_2 gas stream could now be sequestered by a variety of technologies, and the regenerated MEA solution that remains is now in a CO_2-lean condition, which can be reused for CO_2 capture.

An alternative regenerable process for CO_2, using aqua ammonia (consisting of ammonia gas (NH_3), and an NH_4OH solution), offers the possibility of much lower costs during the regeneration phase due to the higher CO_2 loading capacity of aqua ammonia compared to the MEA solution. However, the complex chemistry that occurs when CO_2 is dissolved in aqua ammonia solution is poorly understood – many species co-exist in the solution in an unstable transition. These species could include, but not limited to, ammonium bicarbonate, ammonium carbonate, and ammonium carbamate (all in crystal and aqueous solution forms), plus CO_2, NH_3, and NH_4OH. These byproducts, especially ammonium bicarbonate, could be used as fertilizer or decomposed by heating. During regeneration by heating, the CO_2 could be released from the ammonium bicarbonate/carbonate solution and become available for sequestering. Meanwhile, the ammonium-containing solution could be recycled in a continuous process for reuse as a CO_2 absorbent.

Grant applications are sought to develop further improvements to the aqua ammonia process as a CO_2 concentrator. Approaches must include the development of a three-phase (solid, liquid, and gaseous) diagram of the $NH_3 - CO_2 - H_2O$ system at different temperatures, which would be an invaluable tool in determining optimum operating conditions for the process (including both the absorption and regeneration phases). For example, during the absorption phase, it would be desirable to maximize CO_2 absorption, thus maximizing ammonium byproduct formation; the situation would be reversed during the regeneration phase. If the low- cost CO_2 capture of CO_2 could be developed, the potential capture market would be immeasurable.

d. Instrumentation Systems for Monitoring and Verifying Carbon Sequestration in Terrestrial Systems—New, low-cost methods for determining and verifying carbon sequestration are needed to lower the overall cost of carbon sequestration. Grant applications are sought for new reliable, low-cost instrumentation, diagnostic tools, and measurement systems that can be used to monitor and verify the sequestration of carbon in soil and in above-ground vegetation.

In the soil, low cost technologies are sought that are capable of measuring carbon at one-tenth of the cost and time required to analyze samples with using current methods. Systems must be capable of measuring carbon concentrations at 0.1 percent or less, with a measurement accuracy of $\pm$10%. The soil carbon must be measured at a minimum within the top 30 cm, with measurement at 100 cm below the surface desired. The system can either take *in-situ* measurements or incorporate soil sampling (soil core) techniques for later analyses. Soil sampling devices that are capable of measuring other soil properties (e.g., bulk density and the concentration of such nutrients as phosphorus, nitrates-nitrogen, potassium, magnesium, calcium, and iron) along with the carbon will be considered an advantage. The measurement of these other properties may improve farming practices and reduce fertilizer use, thereby increasing carbon storage and decreasing other greenhouse gas emissions such as nitrous oxide. In addition, the measurement of soil bulk density may be required to determine the mass of carbon in a sample. The bulk density measurement precision should be $0.1 g/cm^3$ with an accuracy of $\pm$10%.

For above-ground vegetation systems, new technologies are needed to measure the carbon stored in above ground vegetation on carbon sequestration projects. The technology must be able to reduce the costs of measuring above ground carbon stored in biomass to 1/10 the cost of current field methods. In trees, current methods use the diameter at breast height to estimate the amount of biomass, and subsequently carbon. However, new remote sensing technologies, which offer the most immediate potential, require that other parameters be used (such as crown diameter and height of the vegetation) to estimate carbon content. The technology must be appropriate for estimating carbon stocks over large geographic areas (10,000+ acres). Because many of these sequestration projects also provide the potential for forest products, technologies that also can estimate forest product potential will be considered advantageous compared to those that only measure carbon storage.

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47. NATURAL GAS AND OIL 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 natural gas and oil. Much of the known reserves of natural gas in the United States cannot be recovered by conventional means, and advanced technologies will be required for extraction. In addition, the utilization of natural gas can be further enhanced by new technology for storage and delivery. With respect to oil, advanced imaging systems are needed to better characterize reservoirs. **Grant applications are sought only in the following subtopics:**

a. Natural Gas Sustainability—In the United States, the economical production of natural gas from conventional and low permeability gas resources will require additional advances in exploration and production technologies. New diagnostic and imaging technologies will be needed to assess the effectiveness of new extraction techniques related to drilling, completion, and stimulation. Therefore, grant applications are sought to develop: (1) advanced seismic-while-drilling technology systems to incorporate advances in high-temperature (above 400 ^{0}F) electronics currently under development at the Department of Energy's National Energy Technology Laboratory (NETL); (2) advanced well logging tools for improved detection of mobile fluid saturations and net pay thickness in thinly bedded sandstone-shale sequences associated with low-permeability tight sands; (3) better borehole and near-borehole systems (including improved acoustic, optical, and electrical tools) for imaging fractures and thin beds that standard logging tools cannot detect – these imaging systems should be capable of measuring fracture dimensions and other properties, such as azimuth, density, spacing, length, flow aperture, saturation, connectivity, and *in situ* stress. Grant applications are also sought for improved multicomponent seismic data analysis, interpretation, and application techniques for detecting variations in lithology, porosity, pore fluid content (i.e. discriminating oil, water, and gas), and bulk reservoir properties by the joint analysis of information derived from s-waves and p-waves. Partnering with industry is encouraged. Applicants are encouraged to review related information on the NETL Website at http://www.netl.doe.gov/scng/index.html.

b. Natural Gas Storage—The current distributed electric generation model in the United States is designed to provide emergency and stand-by power to minimize the impact of electric outages. This service is dominated by diesel generating equipment because of the need for on-site fuel storage. Penetration into this market by mini-turbine and fuel cell systems, which can provide not only emergency/stand-by service but also can contribute to base loads and peak needs, will require safe and efficient means of storing natural gas. On-site natural gas storage would provide protection against electric utility outages and supplement the natural gas arriving via the servicing pipeline during periods of peak demand or at times of low pipeline pressure or availability. Therefore, grant applications are sought to develop and evaluate technology for safe and efficient small-scale, on-site storage of natural gas for distributed electric generation. Partnering with industry is encouraged. Applicants are encouraged to review related information on the NETL Website at http://www.netl.doe.gov/scng/index.html.

c. Natural Gas Delivery Reliability—Maintaining the integrity and reliability of the natural gas distribution and transmission systems across the United States is essential to ensure the availability of clean, affordable energy for homes, businesses, and industries. Natural gas consumption in the U. S. is projected to reach or exceed 36 trillion cubic feet (TCF) per year by 2025, increasing from 22 TCF per year in 1997, and this increase will require not only that the existing natural gas infrastructure be maintained but also that it be expanded. DOE's NETL, through the Strategic Center for Natural Gas (SCNG), recently initiated a new program, Delivery Reliability for Natural Gas, to provide research and development for maintaining and enhancing the integrity and reliability of the nation's gas transmission and distribution network. Grant applications are sought to develop: (1) advanced non-metallic pipeline materials (although some metallic constituents would be acceptable), capable of containing higher pressures (above 300 psi) and suitable for fabrication into pipes from 6 to 20 inches in diameter; (2) sensors, that can be incorporated into or onto the pipe, that detect unauthorized right-of-way intrusion prior to pipeline damage; or (3) improved technologies

or tools for repair of damaged pipe – both metallic (i.e., steel) and non-metallic (i.e., polyethylene) – and suitable for small openings, meaning that "keyhole" or "micro-excavation" technologies would be of particular interest. Applicants are encouraged to review the document "Pathways for Enhanced Integrity, Reliability and Deliverability" (available on the NETL website at http://www.netl.doe.gov/scng/publications/t&d/naturalg.pdf; and the update to that document "Roadmap Update for Natural Gas Infrastructure Reliability" at http://www.netl.doe.gov/scng/publication/t&d/Pittsbugh%20Roadmap%20Update_3-15-02_Final_1.pdf, which summarizes a NETL-sponsored road mapping session to identify priority research needs for the natural gas pipeline infrastructure.

d. Oil Sands and Oil Shale—There are potentially significant amounts of hydrocarbon available in oil sands and oil shale within the United States. Despite several attempts in the past to recover these hydrocarbons, there has not been much success. Grant applications are sought to develop new or improved methods for recovering hydrocarbons from oil sands and oil shale. The research project must include the identification of specific oil sand and oil shale locations within the United States, a review of past and current technology used for their recovery, and a determination of the amount of hydrocarbons available from these locations, updating previous accounts as appropriate.

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