DOE/SC-0008

SBIR

Small Business Innovation Research

STTR

Small Business Technology Transfer

PROGRAM SOLICITATIONS

Closing Date: February 29, 2000

U. S. Department of Energy
Office of Science, SC-32
19901 Germantown Road
Germantown, MD 20874-1290

Major Differences Between Fiscal Years 1999 and 2000 in DOE SBIR and STTR Program Solicitations

- **The Solicitations for SBIR and STTR are combined in this document.**

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

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

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

- **The distribution of final reports has been changed. Three copies of the final report on the Phase I project must be submitted within 90 days after completion of the Phase I effort. The original should be sent to the DOE Technical Project Manager, and two copies to the Grant Specialist at the contracting office which negotiated the grant. A copy is no longer required by the SBIR Program office.**

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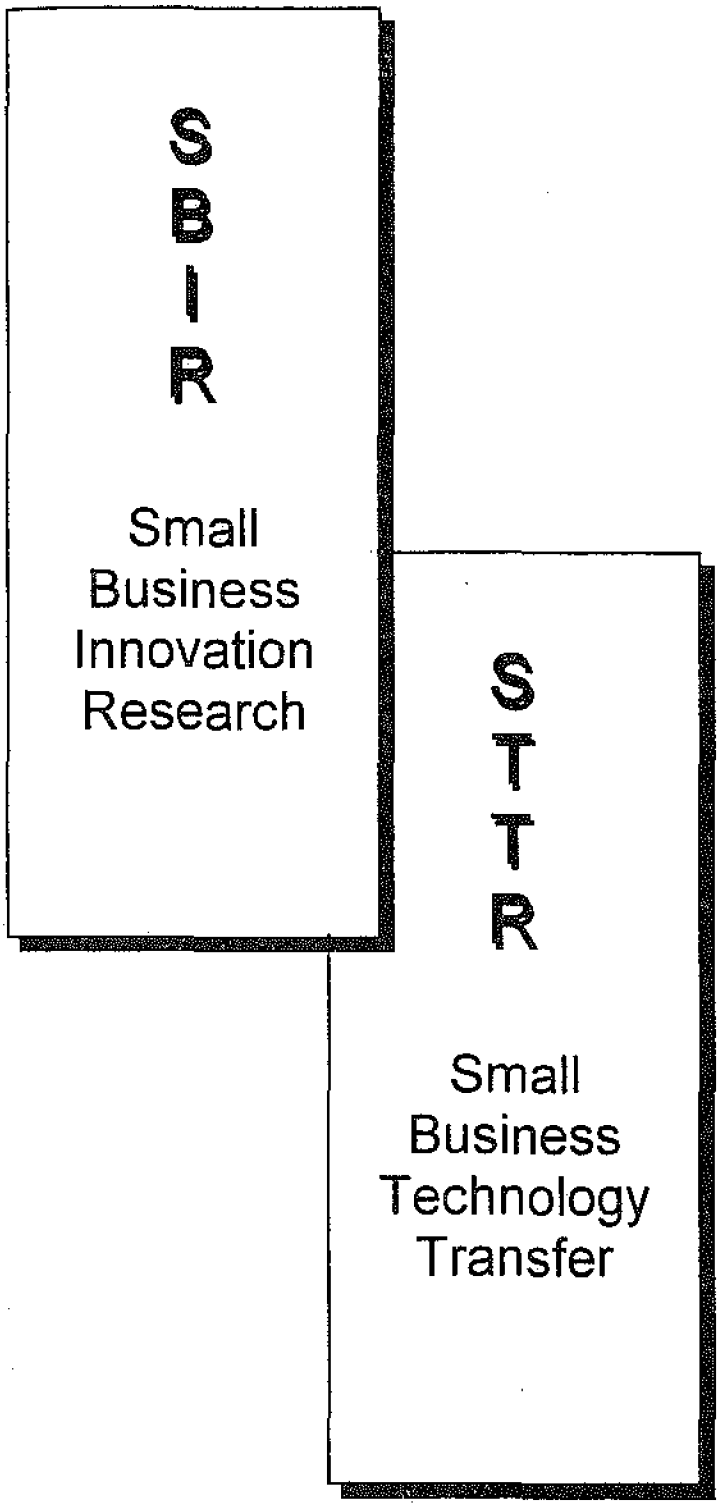

Technical

Topic

Descriptions

TECHNICAL TOPIC DESCRIPTIONS

The technical topic descriptions for this solicitation are given below. The topics are related to the DOE programs and follow the program area overview. Note that grant applications are effectively in competition with other grant applications submitted to those technical topics that belong to a single DOE program area (see Section 4.2).

The text in the first section of each topic gives general and background information for the topic. Each topic is divided into a maximum of four subtopics. A grant application must respond specifically to the description given in one subtopic and not just to the general description at the beginning of the topic; it must comply, however, with any restrictions and exclusions contained within that general description.

PROGRAM AREA OVERVIEW
ADVANCED SCIENTIFIC COMPUTING RESEARCH

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

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

The Mathematical, Information and Computational Sciences subprogram includes research in applied mathematics, high performance computing and communications, and information infrastructure. The program has two major strategic thrusts: (1) the National Collaboratories Program which develops tools and capabilities to permit scientists and engineers working at different facilities to collaborate as easily as if they were in the same building, and (2) the Advanced Computational Testing and Simulation Program which develops an integrated set of algorithms, software tools, and infrastructure to enable computer simulation to better complement experiment and theory.

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. Partnerships with industry include Cooperative Research and Development Agreements, personnel exchanges, and technical consultations with industry scientists and engineers.

1. IMPROVED COMPOSITE MATERIALS AND PROCESSING TECHNOLOGIES

Many technologically important materials and processes have adverse environmental and health impacts which must be mitigated while preserving the crucial attributes of these substances. An excellent example is beryllium (Be) and its compounds. Beryllium metal has very high specific strength and stiffness, making it attractive for lightweight aerospace structures. Beryllium oxide has a unique combination of high electrical resistivity and high thermal conductivity, making it attractive for circuit substrates and components in high-power microwave tubes. The toxicity issues surrounding beryllia are making its use less and less attractive, but no truly comparable alternative materials exist to take its place. The most likely candidate for electronic applications is aluminum nitride (AlN), but many technological hurdles remain before AlN can be considered a viable replacement. These hurdles include fabricability and water sensitivity as well as compatible metallization and brazing processes. **Grant applications are sought only in the following subtopics:**

a. Lightweight Be-Free Alloys for Structural Applications—Grant applications are sought for the development of novel alloy compositions or mechanical

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treatment processes that have the potential to create Be-free alloys with high specific strength and stiffness, comparable or superior to currently-used beryllium alloys. The development or use of novel techniques, such as combinatorial chemistry to rapidly screen new alloy compositions, is especially encouraged. Grant applications focused on combinatorial chemistry must describe in detail how samples will be evaluated in order to obtain reliable measurements of the mechanical properties of interest.

b. High Thermal Conductivity Ceramics—Grant applications are sought for the development of novel Be-free ceramics and ceramic composites that can be used instead of beryllium in applications that require high thermal conductivity, such as microwave tubes, thick-film substrates, heat sinks, etc. Materials that possess high microwave loss (for use as load elements in high-power microwave devices) and high thermal expansion coefficient are also of interest. Both the thermal conductivity and the microwave loss must be comparable or superior to beryllium, and the thermal expansion coefficient must be close to that of beryllium. Grant applications in this subtopic must clearly identify target applications and demonstrate an understanding of the engineering requirements for those selected applications.

c. Metallization and Brazing of Composite Materials—The substitution of AIN, or other ceramic composites, for beryllia in microelectronic applications is presently hampered by a lack of suitable techniques for depositing thick-film circuit elements on the composite substrate. In addition, substitution for beryllia windows and load elements in high-power microwave tubes will require the application of highly-adherent metal coatings to create strong, hermetic joints. In both of these applications, the beryllia substitute may require metallization before the metallic coating can be applied. Grant applications are sought to develop one or more of the following processes for AIN or other ceramic composites suitable for beryllia substitution: (1) highly reliable metallization techniques, (2) techniques for applying metallic coatings, or (3) techniques for brazing the material to metals, particularly copper. For (2) and (3), proposed approaches may or may not include a metallization step. Grant applications in this subtopic must clearly identify target applications (such as microwave tubes, thick-film substrates, heat sinks, etc.) and demonstrate an understanding of the engineering requirements for those selected applications.

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   http://www.amm.com/ref/beryl.HTM

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2. HIGH PERFORMANCE NETWORKS AND APPLICATIONS

The Department of Energy (DOE) currently supports research in advanced computing, high-speed networking, and advanced scientific applications. Grants applications are sought that will enhance and augment this research. Grant applications must clearly state how the proposed research and development will enhance or augment the current research being done in the Department or clearly define the proposed benefit to the DOE. **Grant applications are sought only in the following subtopics:**

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a. Network Technologies—Development of wireless LAN technologies and high speed gigabit networks will allow Internet speeds to increase by two and three orders of magnitude, respectively, from current speeds of 1.5 megabits per second (mbs) as well as allow increased nomadicity and remote connectivity. The utilization of these capabilities on the Internet will require the development and deployment of smarter and more adaptable networking technologies to support the varied requirements of a heterogeneous set of applications and end users. Grant applications are sought to develop such networking technologies in three areas:

Network engineering, in which advanced tools, technology, and services are required to: (1) monitor, analyze, and manage multiple layers of heterogeneous networks; (2) perform effective and scalable routing/switching, including best effort and priority traffic, reliable multicast, real time, and variable or flat accounting/costing mechanisms and protocols for differentiated services; (3) manage lead user infrastructure, which entails the dynamic and secure concurrent support of production and network research traffic (i.e., multiple policy traffic that may be in conflict with one another) on the same infrastructure, as well as the de-aggregation of tributaries; and (4) remote (wireless), reliable and secure network connectivity at higher speeds than currently commercially available for real time operation (to include two way videoconferencing, visualization, and collaboration) and capable of supporting a variety of protocols.

Privacy and security throughout the network, requiring development of tools and techniques for (1) secure and fair means for enabling application and user access and control of network resources; (2) smart network management (i.e., highly capable network management agents, tools and stations) that adapt to a dynamic network infrastructure; and (3) secure and private high speed nomadic or remote access. Grant applications in this area must address appropriate public key infrastructure (PKI) research that supports these efforts and which is interoperable and consistent with industry-driven PKI.

Quality of Service (QOS), which includes such functions as developing: a baseline QOS architecture and semantics; secure admission control mechanisms, including prioritization and accounting/costing; and QOS application program interfaces (APIs) that support cross layer propagation of QOS status and control, exposure of QOS controls directly to the application, and an appropriate set of service monitoring, discovery and validation tools. These characteristics are expected to be deployed in layer 3 IP (Internal Protocol), e.g., RSVP (Resource Reservation Protocol), as well as layer 2 ATM (Asynchronous Transfer Mode), e.g., NNI (Network to Network Interface) signaling. QOS grant applications must also account for two emerging technologies: (1) **seamless infrastructure,** which will require enhanced current peering and interconnection tools, technologies, protocols, and mechanisms for participants in future advanced applications located on various telecommunication carrier and agency networks (areas of interest include inter-carrier and inter-network considerations such as: route peering and data delivery interconnection; user friendly and accessible network management, monitoring, and analysis; QOS and class of service propagation, validation, accounting, and costing; and privacy and security domain and protocol support), and (2) **Ipv6,** currently proposed as the common bearer service of the future, for which QOS grant applications must be coordinated (e.g., through joint proposals or coordinated development) with advanced applications (to at least address specific requirements) and networks (so that the research will have an appropriate test vehicle).

b. Middleware Tools Enabling Applications—Grant applications are also sought for the development of tools in the technology areas of collaboration, distributed computing, digital libraries, remote operations and privacy and security that enable applications. This tool development should be targeted for commercial deployment, optimally "plug and play." Advances are required in the following areas: (1) **security** - a large number of applications will rely on the capability to maintain privacy, confidentiality, and integrity of proprietary data; (2) **data sharing** - digital libraries and other science/technology information banks will be required for network-based applications such as the Genome Data Base; (3) **software sharing** - the capability for scientists at different locations to conveniently share software that supports data analysis, visualization, and modeling; (4) **controlling remote instruments** - communicating with remotely-sited equipment or instruments is required for design and use of remote science facilities, such as advanced light or photon sources, across a network; (5) **remote visualization** for viewing the results of computational simulations (advanced visualization technologies, such as network-integrated, immersive virtual reality devices, would allow multiple design or experimental teams to work together

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across distances to simultaneously observe or analyze data, images, etc.); (6) **scalability** - network technologies used by wide-area applications must be able to be scaled up to support applications at the national scale far better than is possible today; (7) **high end computation and computing resources** - testbeds will need to integrate supercomputers and computational technologies for remote experimentation (where supercomputers may be used for real-time diagnostics, for instrument recalibration, or for real-time modeling of experimental data); (8) **self-organizing networks** – to provide self-adaptation when the physical configuration or requirements for network resources have changed; (9) **nomadicity** - the ability to move resources as needs dictate, including "mobility of access rights" so the network will know how to treat a new resource (this may range from full rights to complete denial of access); (10) **rapid resource discovery capability** - where current network administrators painstakingly document resources, assign rights, and monitor use; in the future, network resources would be discovered as needed (an extreme case would be during the response to a natural disaster or other crisis); (11) **portability and interoperability of applications** - as networking and computing become more ubiquitous, the idiosyncrasies of networks and computers should become transparent to users; (12) **virtual subnetworking** - providing the ability to establish specialized communities of interest (e.g., researchers collaborating on a climate model, prime and subcontractors working on a new product, or a task force developing a new policy); (13) **ease of use** - where the ability to add resources to networks will be as easy as it is to plug in a phone today; and (14) **reliability** - although advanced networking services will be fragile, and suitable only for research when first implemented, the designs must eventually be scalable to full commercial and even military robustness.

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   http://www.er.doe.gov

PROGRAM AREA OVERVIEW - BASIC ENERGY SCIENCES

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

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

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

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

3. HIGH-SPEED WIRELESS DATA-LINK FOR COMMUNICATING FROM DOWNHOLE TO THE SURFACE WHILE DRILLING

In the drilling industry, mud-pulse telemetry (based on the transmission of pressure waves in the mud) has been used as the standard communication link between the downhole and the surface. However, mud-pulse telemetry has a number of limitations: the data-rate is low (about 1 bit/sec), it cannot be used while tripping (when mud is not being pumped), and does not work for underbalanced drilling (aerated muds). Although wired data-links have been demonstrated as technically feasible, they have not met with industry acceptance. Therefore, a wireless high-speed (>1k bits/sec) data-link is needed that would operate during tripping and underbalanced drilling. The data-link must be able to operate in water base, oil base, and aerated drilling fluids. It also must be able to operate in both open holes and cased wells. Furthermore, the data-link must allow for two-way communication; however, the downlink does not need to be high-speed, approximately10 bits/sec would be sufficient.

In this topic, the first three subtopics invite grant applications for improving two alternative approaches to mud-pulse telemetry, electromagnetic (EM) telemetry and acoustic telemetry (based on stress waves traveling in drill pipe rather than pressure waves in the mud), that have already been demonstrated as technically feasible. A fourth subtopic invites grant applications on novel systems. For acoustic telemetry, grant applications are sought for key components that are not currently available. Respondents should clearly detail how they will meet data rate and temperature requirements. Also, since 50 years of borehole telemetry research has resulted in hundreds of patents, respondents should also demonstrate knowledge of past work and the issues surrounding previous attempts. **Grant applications are sought only in the following subtopics:**

a. EM Telemetry Short Hop System—EM data transmission has been used as an alternative to mud-pulse telemetry when mud-pulse telemetry can not be used. The baud rate is similar to mud-pulse telemetry. Grant applications are sought for an EM telemetry system that is capable of transmitting more than 20k bits/sec over more than1000 ft inside the drill pipe and/or casing filled with drilling mud. Grant applications must clearly indicate how the proposed approach will differ from and exceed the performance of existing EM techniques.

b. High-Efficiency Power Amplifier for Acoustic Telemetry Transmitter—The efficiency of converting electrical energy into acoustic energy is very poor. For PZT (lead-zirconium-titanate) actuators, basically high-loss capacitors with impedance from 1 to 5 microfarads commonly used in sonar equipment and barbeque ignitors, only 2 percent of the electrical energy is converted into acoustic energy. Grant applications are sought to develop a high temperature, high efficiency power amplifier for acoustic telemetry that provides an acoustic power output level of 10 watts with an efficiency of at least 25 percent. By matching the mechanical impedance of the transducer to the steel tubulars used for drilling, it has been demonstrated that 10 watts of acoustic energy could be produced from 40 watts of electrical power. In addition, the power amplifier must be able to: (1) operate at 200 degrees C or higher for up to 200 hrs MTBF (even if this means reducing the power levels in the circuit), (2) drive a transducer with a load impedance of 1 to 5 microfarads, (3) utilize battery packs of (+/-) 50 to 150 volts as the power supply, (4) convert the DC source into a time-harmonic signal of roughly 300 to 600 volts amplitude, (5) operate with a bandwidth of 75 Hz or greater and with center frequencies between 650 Hz and 910 Hz; and (6) fit inside a cylindrical volume that is 2.8-in ID, 4.1-in OD, and 24-in length.

c. Acoustic Telemetry Receiver (Sensor) for Coiled Tubing—In existing acoustic telemetry systems, high quality accelerometers are typically employed to sense the acoustic signals in the drill pipe. These accelerometers are usually

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clamped directly to the drill-pipe to detect time-harmonic axial motion. However, innovations in drilling methods have led to the increased use of coil tubing for drilling and servicing wells. Therefore, a novel sensor design is needed to detect telemetry signals in moving coiled tubing. This tubing, which is typically only a few inches in diameter, is pushed into the well without rotation using an injection assembly mounted directly above the wellhead. Grant applications are sought for an acoustic telemetry receiver (sensor) for coiled tubing that: (1) does not need to be clamped directly to the drill pipe, (2) can detect time-harmonic axial motion with an amplitudes of 10μGs or less, (3) can detect frequencies in a band between 500 and 2000 Hz, (4) can detect telemetry signals in moving coiled tubing without being clamped to the tubing, (5) is able to detect the telemetry signal at a location between the wellhead and the injection clamps (this space is approximately 6-in tall and open to view from the rig floor), and (6) is able to provide continuous monitoring of the signal during the time that the injection clamps are moving the coiled tubing into and out of the well.

d. Novel Telemetry Approaches—Grant applications are sought for the following novel telemetry (non-acoustic or EM) systems: (1) long hop system capable of transmitting >1k bits/sec from >10,000 ft or (2) short hop system capable of transmitting >20k bits/sec over >1000 ft inside the drill pipe and/or casing systems.

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4. HIGH-TEMPERATURE ELECTRONICS DEVELOPMENT FOR GEOTHERMAL APPLICATIONS

Advancements in high-temperature electronics are critical to a number of industries including aircraft and automotive engine manufacturing, natural gas production, and geothermal well drilling. This topic seeks to speed the transition of newly developed high-temperature electronics out of the laboratory and into high-temperature commercial applications within the geothermal industry. **Grant applications are sought only in the following subtopics:**

a. Solid-State Temperature Sensor—Knowledge of the geothermal well temperature is critical during drilling and immediately following its completion. Although temperature measuring devices exist in silicon integrated circuits today, they are generally limited to an upper operating temperature of 175°C. Another drawback is that, at present, the cost of a commercial temperature log is approximately $2,000 per well. Therefore, if a lower cost device could be developed, a strong commercial market would be expected in the geothermal industry and elsewhere when temperatures exceed 175°C. Grant applications are sought to develop a simple, solid-state electronic device that measures temperature as a function of current. In addition: (1) the device must be operational for temperatures between 0 and 325°C; (2) the constant current operation must work from nominal voltages of 9 to 20 volts producing a linear current no more than 0.1 mA per degree Celsius; (3) the device must be a two-wire device in order to mate with existing logging

cables; and (4) the low-current, temperature must be able to operate over very long (15,000 ft) logging cables using commercially available current meters.

b. Pressure/Temperature Tool—One of the most useful tools in the geothermal industry is the pressure/temperature tool (the PT tool) that measures and records pressure and temperature information as a function of depth. At present, these tools are produced using low-temperature, commercially available electronics housed within a heat shield. However, the heat shield only protects the tool from the high-temperature, well-borne environment for a short period of time -- the tool must enter and return from the well within that limited time duration or it would be destroyed. Because the loss of a PT tool would cost $15,000 to $30,000, well owners are inhibited from using this very valuable instrument. If a low-cost tool could be developed that was capable of operating unshielded in a geothermal well, it would be positioned to capture about 60 percent of the worldwide logging market for geothermal wells. Grant applications are sought to employ innovative, high-temperature electronics in developing a low-cost PT tool that (1) can survive temperatures greater than or equal to 250°C without heat shielding, (2) can survive pressures greater than or equal to 8000 psi, (3) have a temperature accuracy less than or equal to 2°C absolute error, and (4) have a pressure accuracy within 5 percent of the full scale reading of 10,000 psi.

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5. NEUTRON INSTRUMENTATION

The Department of Energy supports a number of large-scal national user facilities that provide intense beams neutrons. As a unique and increasingly utilized resear tool, neutrons have made invaluable contributions to tl physical, chemical, and biological sciences. The Departme is committed to enhancing the operation and instrumentatic of its present and future neutron science facilities so th their full potential is realized. **Grant applications a sought only in the following subtopics:**

a. Neutron Detectors—Grant applications are sought develop improved neutron detectors and associate electronics needed for DOE's existing and proposed steady state and pulsed neutron scattering facilities (References 3). New detectors must represent substantial improvemen in one or more of the following parameters: efficiency short wavelengths, high counting rate capability, high spati resolution in one or two dimensions, cost per unit area, adaptability to unique geometries. Detectors for pulse neutron applications must be able to identify the time arrival of each neutron. All detectors must have low intrinsi dark count rates and low sensitivity to gamma radiatio

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b. Neutron Optical Components—Grant applications are sought to develop novel or improved neutron optical components for use in neutron scattering instruments (References 1,3-4). 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.

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* See Section 7.1

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

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

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

b. Alternative, Low-Cost Separators for Lithium-Based Rechargeable Batteries—There is also a need for low cost, alternative separators for lithium-based rechargeable batteries, especially separators that offer reduced materials costs. Grant applications are sought for separators that can be inexpensively manufactured and easily substituted into current battery systems. The cost of the separators should be estimated on a $/m^2 basis, and the key performance measure for the separator should be the specific conductivity when used in a standard Li-ion system. Performance, when used

in a Li-ion cell, must be at least comparable to existing Li-ion technology in terms of power density, expected life, etc. in the temperature ranges to which current systems are exposed. In addition, chemicals used must not be incompatible with current spystems, must not be harmful to the environment, and must be completely recyclable.

c. Alternative Polymeric Electrolytes for Lithium Based Batteries—Polymeric electrolytes are a critical component of advanced batteries. Grant applications are sought to develop advanced lithium-ion conducting polymer electrolytes and associated manufacturing processes capable of supporting advanced battery technologies for high power (for hybrid vehicles) or high energy (for electric vehicles) storage. Desired electrochemical properties should include: ionic conductivity greater than 10^{-3} S/cm, electrical conductivity less than 10^{-7} S/cm, electrical breakdown greater than 5 volts/m, lithium ion transference number greater than 0.3, and stability of the electrolyte adjacent to a cathode material up to 5 volts versus lithium. (If the polymer is a single ion conductor, these parameters may be suitably modified, provided that equivalent performance is obtained.) Desired mechanical properties should include: tensile strength of 2 Mpa, melting point greater than 250°C, glass transition temperature less than -70°C, and molecular weight greater than 10^5. In addition, proposed lithium-ion conducting materials should be capable of being coated and dried, or extruded, onto a previously processed electrode layer; sufficiently hard to inhibit growth of dendrites when used with a metallic lithium electrode; and sufficiently sticky so as to form a good bond with a metallic lithium electrode. Materials costs should be low and support a potential battery cost of less than $100 per kilowatt-hour.

The Phase I effort should focus on formulating samples of the polymer and demonstrating that its properties meet the above generic requirements or their equivalents. Ultimately, the capability of the technology should be demonstrated by fabricating cells with a capacity of at least 1 Ah and preferably larger. The cell specifications should be evaluated by the procedures of the United States Advanced Battery Consortium or the Society of Automotive Engineers (see references below).

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** See Section 7.1

7. RECOVERY, RECYCLE, AND RE-USE OF POLYMERS AND PLASTICS

The energy and environmental benefits of recycling are significant. Accordingly, an infrastructure presently exists to support the recycling of certain commodity materials, especially metals from a variety of sources such as industrial scrap and consumer durables (e.g., automobiles, appliances, and computers). For example, steel and aluminum are currently recycled at rates in excess of 60 percent. The recycling of these materials, along with paper and glass, are estimated to conserve 1.5 quad of energy per year. A comparable amount of energy could be saved by recycling polymers and plastics, yet the total recycle rate of these materials is less than 2 percent. Although some plastics, such as high-density polyethylene (HDPE) from beverage bottles, are successfully recycled, new technologies and approaches are required to increase the recovery, identification, and re-use/recycle of polymers and plastics used in industrial and consumer durable applications. Grant applications related to the collection/transportation of materials for recycling and technologies for conversion of organic materials to energy (e.g., waste-to-energy) are outside the scope of this topic and will be declined. **Grant applications are sought only in the following subtopics:**

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

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

Lastly, grant applications are sought to develop innovative thermo-chemical approaches, especially thermosets, for the recovery of monomers and chemical precursors from plastics. Of particular interest is the use of thermo-chemical conversion to remove paints, adhesives, and sealants from waste plastic parts.

b. Re-use and Conversion of Recovered Materials—Oftentimes, plastics and polymers cannot be directly re-used because aging effects from long-lived first applications may have changed the nature of the material, or residual contaminants in the recovered material may not be cost-effectively removed, or the recovered material cannot be directly reprocessed, such as with thermoset plastics. Therefore, grant applications are sought to develop viable uses and markets for recovered plastics and polymers. Proposed efforts must demonstrate that the new uses/markets will (1) absorb a large volume of material at acceptable economics, and (2) provide significant energy savings in terms of reduced crude oil imports. The latter saving could come about by direct replacement of virgin resin, reduced use of other energy-intensive materials, or extensions in the useful life of petroleum based products. Areas of interest include the use of recycled polymers as asphalt additives and as cement and concrete additives.

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Grant applications are also sought to develop technologies and processing techniques to provide for the reuse of mixed plastics. The technology should be able to take a polymer mixture that is not broadly useful, because of gross phase separation and/or residual contamination, and make it more useful. Possible approaches include physical processing, the use of additives, or chemical reactions that act on the mixture.

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8. MEMBRANES FOR ADVANCED INDUSTRIAL SEPARATION TECHNOLOGIES

Industrial separations recover, isolate, and purify products in virtually every industrial process. Pervasive throughout industrial operations, conventional separations 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, 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 in the chemical and petrochemical industries include producing oxygen-enriched air for combustion, recovering and recycling hot wastewater, volatile organic carbon recovery, and hydrogen purification. Membranes have also been combined with conventional techniques such as distillation to deliver improved product purity at a reduced cost. Membrane separations promise to yield substantial economic, energy, and environmental benefits leading to enhanced competitiveness by reducing annual energy consumption, increasing capital productivity, and reducing waste streams and pollution abatement costs.

Despite the successes and advancements, many challenges still face the adoption of membrane technology. Technical barriers include fouling, instability, low flux, low separation factors, and poor durability. Advancements are needed that will lead to new generations of organic, inorganic, and ceramic membranes. These membrane 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. **Grant applications are sought only in the following subtopics:**

a. Membrane Materials with Improved Properties— Grant applications are sought to develop lower cost

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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), (3) suitability for separating hydrophilic compounds in dilute streams, (4) ability to separate by differences in chemistry, size, and/or diffusivity, and (5) capability to reverse separation order. Particular membrane materials of interest include nano-composites, mixed organic/inorganic composites, and chemically inert materials. Particular processes/systems of interest include lower cost, small volume oxygen production; oxygen separation/oxidative chemistry; oxidation/dehydrogenation reactions; and membrane reactors. 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. Enhanced 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 membrane process systems using currently existing membranes. The focus should be on the development of integrated membrane systems that can be shown to be robust in real-world processes (e.g., hydrogen separation/recovery, inert gas removal, isomer separation, aromatic/nonaromatic 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) development of scalable low-cost membrane manufacturing techniques, (3) development of manufacturing technologies that would reduce the cost of membrane modules, (4) improvement of long-term operability of membranes systems with anti-fouling and anti-flux declining schemes, and (5) methods to regenerate membrane performance and lower membrane maintenance costs. The integration of membranes with other technologies to address specific process issues would also be of interest. Grant applications should also include an integrated process evaluation and an economic analysis along with the R&D effort.

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

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9. REACTIVE SEPARATIONS

Reactive separations utilize close coupling of separation and chemical reactor systems, often in a single unit, to improve the yields 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 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

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applications are sought to adopt the reactive distillation process to other 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. Unfortunately, it will not be enough to simply apply membrane technology to existing reactor processes. Rather, it will be necessary to identify and exploit new, more efficient chemical pathways that membrane reactors would make possible. Grant applications are sought to develop improved membrane reactors for particular applications with outstanding economics compared to existing technology. Areas of interest include developing membrane materials with improved reliability and performance (e.g., with better selectivity, permeability, stability), and developing unique approaches to engineering membrane contacting devices.

c. Reactive Separations For Waste Reduction—Most industrial interest in reactive separations is due to its potential to increase product yields and improve the economics of a number of important synthesis processes. However, the increased product yield also provides an opportunity for decreasing waste generation. Grant applications are sought to develop reactive separation systems 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, and the improvement of waste treatment efficiencies.

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10. DEVELOPMENT OF NONAQUEOUS ENZYMES FOR CHEMICAL PRODUCTION

The need for energy efficient and environmentally-friendly syntheses requires technical innovation as well as industrial adoption of new technologies. Enzymes are currently being examined as candidates for a new class of industrial catalysts because of their high specificity, stereo selectivity, and synthesis capabilities. However, enzymes tend to function in aqueous systems at moderate temperatures and pressures. Because almost all chemical

processes are carried out in organic media under high temperatures and pressures, chemists, enzymologists, and biochemical engineers are currently attempting to generate nonaqueous enzymes, or biocatalysts, that can withstand the needed organic chemical processing requirements.

Once developed, new biocatalytic systems could either be integrated into existing process routes or used as stand-alone operations. Possible benefits include: replacement of multiple chemical synthesis steps with a shorter pathway, elimination of unit operations, significantly higher overall yields, improved operating conditions (e.g., by lowering temperatures and pressures – even for nonaqueous bioprocesses or extremophiles), reductions in capital investment and associated operating and ES&H costs, less frequent solvent changes, utilization of less toxic reagents, and easier treatments for waste streams. Considered together, these changes would save both feedstock and energy consumption.

Grant applications must show how the proposed approach will impact one or more of the following problems associated with many organic chemical processes and synthesis routes: (1) yield losses accumulating from multiple reaction steps, (2) use of toxic or hazardous materials and reagents, (3) production of undesired byproducts, (4) losses due to incompatible solvents between process steps, (5) generation of waste streams that require treatment, and (6) employment of dangerous operating conditions. **Grant applications are sought only in the following subtopics:**

a. Extreme Biocatalysts—If enzymes or microbes could be found, engineered, or adapted to operate in the extreme environments that occur in typical organic media, the chemical process industry could benefit from significant improvements in energy efficiency and environmental stewardship. Grant applications are sought to extend biocatalytic activity in solvent, supercritical, saline, or dry environments. Grant applications are also sought to extend catalytic capabilities beyond hydrolysis reactions into redox reactions and others, which may include the use and recycle of cofactors. Grant applications must explain how or why the proposed biological catalysts will function in the extreme environment.

b. Non-Aqueous Enzyme Bioprocessing—Barriers to the utilization of new biocatalysts could be overcome if the environment in which they operate were more favorable. Grant applications are sought to control and/or modify t effects of nonaqueous environments on the biocataly Grant applications are also sought to design new continuo reactors or separations for the effective utilization of the catalysts and conditions.

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* See Section 7.1.

11. INTEGRATIVE ANALYSIS OF GENE EXPRESSION IN PLANTS AND NON-MEDICAL MICROBES

Recent developments in large-scale genome sequencing nov allow an increasing number of genes to be identified isolated, and characterized. The challenge of the future is t transform our knowledge of the regulation and expression o individual genes and gene sets, which constitute a metaboli pathway, into a broader perspective and understanding o

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how multiple genes are integrated and coordinated within the genome of an organism. Collectively, photosynthetic plants and microorganisms represent a broad array of biosynthetic and metabolic capabilities. The manipulation of the networks of genes in a genome could lead to important energy-related benefits, including the synthesis of high-value chemical feedstocks and biofuels or the efficient conversion of energy renewable resources.

High-density, multigene analysis of genetic information, through the use of *in vitro* microarray technology, is emerging as an efficient high throughput method by which to bridge the gap between DNA sequences and the functions of individual genes or gene sets. These microarrays, often referred to as "gene-chips", contain orderly arrays of biological macromolecules such as DNA or proteins attached to a solid support, usually a microscope slide; and the arrays can be assayed for interactions with other relevant macromolecules. In current applications, the display of DNA fragments or oligonucleotides spots in microarrays is followed by hybridization with fluorescently-labeled mRNA-derived probes. The detection of fluorescent signals emitted from each hybridizing spot result in a qualitative profile of gene expression. Even more significantly, a quantitative perspective on gene sets is provided by the broad dynamic range and extreme sensitivity of the signal output.

Such DNA-chips are one example of the advantage of miniaturizing assays to increase data analysis, reduce the cost per test with cheaper disposable devices, and achieve high sample throughput. They promise to provide an effective and more economical way to simultaneously identify and track the presence or activity of multiple genes. Such high density arrays could be designed for a variety of specific assay purposes and have the potential to enormously speed studies in gene identification, gene expression, and gene function (see references 1-5). **Grant applications are sought only in the following subtopics:**

a. High-Density, Multigene Assay Systems—Grant applications are sought to create high density, multigene assay systems, specifically for tests on plants and non-medical microbes, in order to develop genetic information that could be used to influence some important aspect of the National energy picture. The effort must not only demonstrate proof-of-concept, but also demonstrate how the particular genes assayed would be manipulated to significantly impact an energy-relevant system. Grant applications must also address: (1) the novelty and utility of the probes themselves (i.e., the series of short oligonucleotides or longer gene-length segments to be assayed), (2) the ability of either the chip design or other high-density array to utilize the available genomic sequence data, (3) how data generated from the high density array will be handled and analyzed (e.g., the informatics), (4) the significance of the approach to plant and microbial research as well as to the related energy advantage, and (5) the outlook for economic benefits. Grant applications that focus only on engineering incremental improvements in instruments used to create the high-density array are not of interest and will be declined.

b. High-Density, Combinatorial Protein-Based Microarrays—Proteomics, which is functional genomics at the protein level, includes the study of global changes in protein expression, the systematic study of protein-protein interactions through the isolation of protein complexes, and the combinatorial study of protein-ligand interactions (see references 6-10). Grant applications are sought to create high-density combinatorial protein-based assay systems, specifically to acquire proteomic information in plants and non-medical microbes. Areas of interest include: (1) development of novel technologies for the construction of libraries of proteins or peptides that can be functionally screened in an *in vitro* environment, (2) design of novel protein mimics with enhanced function, and (3) development of novel technologies for *in vitro* small molecule or protein-interaction screening. The effort must not only demonstrate proof-of-concept, but also demonstrate how the particular proteins assayed would be manipulated with an energy-relevant outcome. Grant applications must also address how data generated from the high-density protein array will be analyzed with respect to database and informatics management, as well as the significance of the approach to plant and microbial research and the related energy and economic benefits. Grant applications that focus only on engineering incremental improvements in instruments used to create the high-density array or on refining mathematical models for rational protein evolution or design are not of interest and will be declined.

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

To contribute to a healthy citizenry, BER supports fundamental research and technology development needed for mapping the fine structure of the human genome, which will provide the valuable information needed to identify disease genes and develop broad therapeutic and diagnostic strategies. BER projects also develop advanced imaging and other medical technologies, including highly sensitive radiotracer detectors, radiopharmaceuticals and boron compounds with affinities for tumors. In support of the nation's biomedical, pharmaceutical, and environmental activities, BER projects make use of unique facilities at the Department of Energy (DOE) national laboratories to determine biological structure and how it relates to function at the molecular and cellular level.

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

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

12. GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

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

a. Genomic Analysis Technologies—Several genomic analysis resources and technologies, initially developed under basic research grants, have now matured to the point where commercialization has become a distinct possibility. Grant applications are sought to further develop one or more of the following technologies, leading to kits or services that could be offered for sale: (1) clone libraries derived from single copy vectors, such as BACs (bacterial artificial chromosomes) and fosmids; (2) resources for more economical sequencing of BAC insert ends; (3) resources and methodologies for finishing of draft sequences; (4) economical kits of STS primer pairs, to support analyses of "gene families" across populations.

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

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

d. Informatics Support of Functional Analysis—By the year 2001, it is expected that the draft human genome sequence will be completed, in addition to those of several model (non-human) organisms and numerous microbes. At that time, computational support for the functional analysis of these immense information resources will be of increasing importance. Grant applications are sought to further develop software and computation tools for the processing and

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analyzing of genome scale information resources and large sub-families thereof. Grant applications must demonstrate that the tools will lead to services that will aid users who are non-specialists in computer sciences, and (2) that the services will be complementary to, rather than directly competitive with, public and private sector services already well established.

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World Wide Web Information

1. BAC (Bacterial Artificial Chromosomes) related sites
   a. End Sequencing
      (1) University of Washington Department o Molecular Biology
      http://www.htsc.washington.edu/
      (2) The Institute for Genomic Research
      http://www.tigr.org
   b. History - Sequence Tag Connectors Production o Human BACs
      http://www.ornl.gov/meetings/bacpac/index.html
   c. National Center for Biotechnology Information
      http://www.ncbi.nlm.nih.gov
   d. Production

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(1) Caltech Genome Research Laboratory
http://intorma.bio.caltech.edu/idx_www_tree.html
(2) Roswell Park Cancer Institute BACPAC Resource Center
http://bacpac.med.buffalo.edu/

e. Protein Data Bank of the Research Collaboratory for Structural Bioinformatics
http://www.pdb.bnl.gov/

f. U.S. DOE Office of Biological and Environmental Research
http://www.er.doe.gov/production/ober/ober_top.html

2. Fibre FISH (Fluorescence *In Situ* Hybridization)
http://www-hgc.lbl.gov/instr/weier.html

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

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

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

13. MEDICAL SCIENCES

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

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

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

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

b. Radiopharmaceutical Development for Radiotracer Diagnosis and Targeted Molecular Therapy—Grant applications are sought to develop: (1) radiolabeled compounds that could have applications as radiotracers for radionuclide imaging technologies such as positron emission tomography and single photon emission computed tomography; (2) improved and simplified production of radiolabeled compounds through the use of mini-accelerator technology or automated radiochemical analysis/synthesis techniques; and (3) radiopharmaceuticals for targeted molecular therapy. Of particular interest are radiochemical, synthetic, and combinatorial molecular engineering approaches. All efforts should ultimately result in a product for nuclear medicine use.

c. Advanced Imaging Technologies—Grant applications are sought for new, sensitive, high resolution instrumentation for radionuclide imaging. The instrumentation should advance the application of radiotracer methodologies for imaging molecular biological functions including cell communication and gene expression *in vivo*. Areas of interest include the development of: (1) new detector materials and detector arrays for three-dimensional, positron

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emission tomography; (2) software for rapid data processing and image reconstruction; and (3) methods of integrating *in vitro* and *in vivo* instrumentation technologies for the real time molecular imaging of biological function and for new drug development and utilization.

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

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14. BIOLOGICAL CARBON SEQUESTRATION RESEARCH AND TECHNOLOGY

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

The DOE is developing a comprehensive carbon management program to develop innovative scientific and technological solutions, and reverse the current increase in greenhouse gases. A DOE working paper on carbon sequestration science and technology (see reference 1) describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems including a discussion of advanced biological processes and chemical approaches. This topic is concerned with the biological conversion of atmospheric CO_2 into relatively stable organic or inorganic forms, thus fixing the gas either as usable commercial products or as inert environmentally neutral forms. To attain this goal, research is needed to identify and enhance natural systems that facilitate the long term fixation or sequestration of large quantities of carbon i.e., 10,000 to 100,000 tonnes or more of carbon per year.

Grant applications must provide for a systematic evaluation of proposed biological mechanisms and carbon sequestration systems and describe any by-products expected to be produced. (Production of value-added by-products by the organism is highly desirable.) Estimates of the amount of CO_2 fixed must be provided, and any assumptions concerning quantities and conditions for carbon fixation and sequestration must be clearly defined. Feasibility tests (analytical, bench, or field) performed in Phase I must demonstrate the potential for significant reduction in atmospheric CO_2 upon scale up. Grant applications proposing only computer modeling without physical testing will not be considered.

Two DOE Centers for Carbon Sequestration Research have been established at national laboratories. These Centers

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include both laboratory and university participation. One Center is investigating carbon sequestration by terrestrial ecosystems, and the other focuses on carbon sequestration by oceans. Applicants should explore collaboration with these Centers by contacting one of the directors listed below:

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

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

Grant applications are sought in only the following subtopics:

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

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

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

For either (1) or (2), processes must be developed for producing the CO_2-fixing microorganisms in large quantities. An engineering system, which employs the microorganisms for the eventual large scale utilization of carbon in commercially important applications, should be designed and tested by the end of Phase II. Information on rates of carbon fixation (see Introduction for approximate quantities) and the generation of high-value product would need to be obtained.

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

Grant applications are sought to understand the biological pathways and mechanisms that could lead to increased quantities of carbon sequestered in "natural" systems, determine rates and quantities of carbon sequestration by terrestrial biotic systems, and develop technology to enhance carbon sequestration by terrestrial ecosystems. Areas of particular interest include the identification or development of one or more of the following:

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

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

(3) methods for altering functional interactions of ecosystems, and/or for modifying the ecological relationships among terrestrial organisms, that could

potentially shift the carbon balance of ecosystems in the direction of greater carbon sequestration and increased storage of "natural" long-lived organic compounds;

(4) methods for accelerating transformations of labile vegetable matter into carbon release-resistant soil humus.

c. Benthic Carbon Sequestration—In order to significantly enhance carbon sequestration in benthic environments, grant applications are sought to:

(1) identify marine organisms and determine what factors maximize their CO_2 utilization and the formation of carbonates, and develop technology to exploit these factors to enhance CO_2 sequestration in marine benthic environments without seriously disturbing overall benthic ecology. (As an example, these processes could include sequestration and burial of carbonate rich plankton such as coccolithophorids.)

(2) identify benthic ecosystems and associated sediments that could be manipulated to accelerate CO_2 sequestration, and demonstrate how the manipulation of organisms' genome or the community composition could potentially shift the carbon balance of ecosystems in the direction of greater carbon sequestration and the storage of "natural" long-lived organic compounds.

For either of the above, it may be advantageous (though not a requirement) to collaborate with planned deep sea campaigns/experiments associated with engineered approaches to possible deep ocean disposal of CO_2. In Phase I, a possible outcome of the collaboration could be an integrated plan for companion studies of deep ocean ecological effects related to in situ changes of CO_2 chemistry, pH, and other biophysical factors on which benthic ecosystems are dependent. In such cases, the scope of the scientific studies must be clearly described, including firm documentation that the deep sea campaigns/experiments will occur within the two-year Phase II period and that the plans for the ecological effects research are compatible with the mainline deep sea programs.

d. Biohydrogen Production—Hydrogen is considered to be an environmentally desirable fuel since its combustion product (water) is non-polluting and can be produced in renewable energy systems. Many photosynthetic microorganisms are capable of consuming CO_2 from the atmosphere and simultaneously generating hydrogen. Maximizing this process and ultimately, producing hydrogen at commercial quantities is the ultimate goal. Grant applications are sought to develop hydrogen production processes using new biological organisms capable of capturing light and producing hydrogen by splitting water molecules. Since a number of organisms have been identified as capable of hydrogen production by photosynthesis or biophotolysis, the use of novel organisms not hitherto considered are of particular interest.

With the organisms most commonly used to produce hydrogen by biophotolysis, the enzyme responsible for splitting the water molecule (hydrogenase enzyme) is inhibited by one of the products it produces (oxygen). Therefore, grant applications are also sought to develop a means of avoiding or mitigating hydrogenase inhibition thereby allowing larger quantities of hydrogen to be produced.

Lastly, grant applications are sought to develop and test new organisms capable of efficiently utilizing low-value hydrocarbon waste streams (sugar cane, bagasse, straw, etc.) for production of hydrogen.

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15. 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, that offer the potential for future carbon sequestration. New and innovative methods of measuring intrinsic carbon quantities are also needed.

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 atmospheric media.

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) to a real extent of ecosystems (hectares to square kilometers). 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.

Two DOE Centers for Carbon Sequestration Research have been established at national laboratories. These

Centers include both laboratory and university participation. One Center is investigating carbon sequestration by terrestrial ecosystems, and the other focuses on carbon sequestration by oceans. Applicants should explore collaboration with these Centers by contacting one of the directors listed below:

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

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

Grant applications are sought only in the following subtopics:

a. Sensors for Measurements of 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 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 system must be applicable for forests, grasslands, shrub lands, agricultural lands, and 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 approxima 0.25 tonnes of carbon per hectare per year), with less thar percent uncertainty. For measuring emissions, the ser system must be located at a point remote from the actual of CO_2 release and provide an accuracy of approximately ppm or less.

For both source and sink measurements, information mus provided on the accuracy (e.g., in percent of emissions tonnes per day) of the apparatus proposed. The sen system must be durable in the full range of non environmental conditions and exposures including expos to dust, rain, snow, heat, extreme cold, and fog. Operat in unattended, remote locations for weeks at a time, with degradation of the measurement, is also required; howe daily communication with the system for monitor performance and detecting potential operational proble would be desirable.

The interest is in measurement systems that are differ from, or which substantially augment, existing eddy fl (covariance) and routine monitoring of atmospheric C concentrations. In particular, grant applications proposing *situ* or in-stream measurement of flue gas emissions will declined, as will applications that offer only incremental marginal improvements to existing measurement system

b. Novel Measurements of Organic Substances a Carbon Isotopes in Terrestrial and Atmosphe Media—Improved measurement technology is needed better characterize processes involving carbon trar formations of soil, vegetation, and associated ecosyst components and exchanges with the atmosphere. Tl includes both carbon content and isotopic measurements organic matter in soils and other solid substrates, as well the carbon content of biological tissues in vario components (e.g., phytomoss, detritus) of terrestr ecosystems.

Grant applications are sought for measurements of carb content in the atmosphere, vegetation, soil, and other e vironmental media. For measurements involving the carb content of biota and soil, grant applications mu demonstrate that these measurements can be used to predi changes in carbon quantities and/or fluxes involving maj components of ecosystems, with an accuracy on the order 10 grams per square meter or less. Quantification of sp tially resolved aggregate estimates of terrestrial carb

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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.

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 must be accomplished by *in situ* and/or non-invasive means and/or remote sensing of organic carbon forms across a range of both temporal scales (from seconds to days) and spatial scales (from millimeters to kilometers), depending on the system being observed. Instruments must be portable and deployable in remote locations, and must not adversely impact the site of deployment.

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16. 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 the specific subtopic area. 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 for all 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. High Accuracy Sensors for Routine Balloon-Borne Measurements of Atmospheric Thermodynamic Properties—High accuracy measurements of atmospheric parameters, particularly water vapor, are required from balloon-borne, disposable, lightweight, low cost, high precision instruments to support atmospheric and climate research. Grant applications are sought to develop sensors for balloon-borne, high accuracy measurements of wind velocities and direction, temperature, pressure, and water vapor concentrations from point of launch to at least 20 km altitude. The sensors must achieve one percent accuracy with high resolution, low cost, and be contained in a light-weight package. For winds, temperature, and pressure, these requirements represent modest improvements over current systems. However, for the water vapor sensor, which is of primary interest, a fundamentally new approach is required to provide high accuracy measurements up to very high altitudes, low water vapor concentrations, and temperatures down to at least minus 60 degrees centigrade. One percent accuracy with high time resolution is desired for relative humidities near 100 percent at minus 60 degrees.

Although this subtopic focuses on the development of new water vapor sensors, integration into a lightweight, cheap, and environmentally sound sensor package must also be demonstrated. The total sensor package must be expendable, must not exceed the current radiosonde weight of about eight ounces, and must meet Federal Aviation Administration requirements. Sensors must recover quickly from possible wetting by clouds and rain. Utilization of the Global Positioning System is required for navigation, if necessary. Reflecting the large number of launches desired, a total unit cost near that of current sondes is desired. Grant applications that make only incremental improvements to existing technologies will be declined.

b. Radiometric Instrumentation—Measurements o shortwave solar radiation (0.3 to 3.0 micrometers) an thermal radiation (3 to 100 micrometers) provide necessar information about the chemical and physical state of th atmosphere and earth's surface. Current broadband sola instruments include pyranometers, pyreheliometers, an shadowband radiometers while solar spectral instrument include scanning filter photometers, shadowban radiometers, and spectroradiometers. Thermal instrument include broadband infrared radiometers (pyrgeometers) interferometers, and grating spectrometers. Grant appli cations are solicited to develop radiometric instrumentatio or radiometer components that: (1) improve curren performance of broadband shortwave radiometers (e.g., it i desirable to achieve consistent one percent accuracy b eliminating the need for domed covers and/or other source of uncertainty such as angle of incidence, temperature pressure, and humidity effects on detectors, optica components, and windows); (2) significantly reduce drift poor angular response, dome and window contaminatio (e.g., dust and water) errors, nighttime offsets, therma imbalance errors, leveling sensitivity or other sources o error; (3) significantly reduce the cost of ancillary equipmen such as solar seekers and trackers without degradin performance; or (4) improve the current performance o pyrgeometers to measure hemispherical irradiance in th infrared (3 to 50 micrometers) region (e.g., it is desirable t avoid contamination by solar radiation and to develo improved methods of calibration). Applicants may focus o critical components and ancillary equipment for radiometer including detectors, radiation standards and calibratio methods, filter systems and monochromators, and sola tracker/seekers. Applications that make only incrementa improvements to existing radiometric devices will b declined.

c. Automatic Measurement and Characterization o Cloud Particles—There is a need to develop miniaturize instrumentation for automatic measurement and char acterization of cloud particles. Grant applications are sough to develop instruments for measuring the size of clou particles from about 5 to 1,000 μm and provide informatio on particle shape and the degree of particle riming. O particular interest are instruments that can also measure th scattering phase function and provide some measure o polarization properties. Data from the instrument must b recorded digitally (i.e., not on a VCR) and particle sizin must be accomplished without the need for extensive manua

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analysis of the data. Instruments must be capable of operating continuously in moderate icing conditions and should weigh less than 8 kg. The instrument must also be suitable for deployment on tethered balloons/kite platforms and small, unpiloted aerospace vehicles (UAVs).

d. Instrumentation for Characterizing Organic Substances in Aerosol Particles—Important insights into atmospheric pollution can be gained by understanding the characteristics and temporal changes of organic substances in ambient atmospheric aerosol particles with diameters less than about 2.5 micrometers. Grant applications are sought to develop instrumentation for real-time measurements that will: (1) provide accurate estimates of both mass and speciation of organic matter as a function of particle size; (2) detect the changing degree of oxygenation of the organics in aerosols, in order to evaluate the photochemical evolution of the organic aerosol; or (3) identify 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.

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17. ADVANCED MONITORING TECHNOLOGIES FOR SOILS, SEDIMENTS, AND GROUNDWATER

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

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

a. Biosensors and Associated Monitoring Technologies—There is a need for sensitive, accurate, and real-time monitoring of geochemical and hydrogeologic processes and their interactions with biological organisms in soil, sediment, and groundwater environments. Uses for such environmental measurement capabilities range from bioremediation of hazardous wastes in the subsurface to monitoring of contaminant movement in soils, sediments and groundwater. Many new technologies in biomolecular and gene probe-based assessment have been created in the laboratory; yet, beyond the clinical environment, few have reached the standardized, instrumented, or automated state required for application in soils and subsurface environments.

Grant applications are sought to develop robust but sensitive biosensor devices (devices employing biological molecules or systems in the sensing elements), or critical technologies for them, that can be used in the field for monitoring soil, sediment, or groundwater processes or parameters. Also of interest are integrated biosensing and controller/signal processing systems for autonomous or unattended measurement applications. Sensors and systems proposed must be able to detect geological, biological, chemical, or physical processes that transport, disperse, and transform energy-related materials in soils and the subsurface. Grant applications must address the environmental significance of the parameter to be monitored by the biosensing system. Biosensing systems may incorporate, but are not limited to, whole cell biosensors (chemoluminescent or bioluminescent systems), enzyme or immunology-linked detection systems, membrane lipids, or DNA/RNA probe technology with amplification and hybridization. Minor adaptations of readily available materials or hardware for such use will not be considered responsive to this subtopic.

b. Rapid Molecular Analysis of Microorganisms—The DOE is interested in research to support the use of naturally occurring communities of microorganisms, consisting of a variety of species, for the *in situ* bioremediation of metals and radionuclides in soils, sediments, and groundwater. (Metals of interest include chromium, lead and mercury; radionuclides of interest include cesium, plutonium, strontium, technetium, and uranium.) However, before remediation activities can be addressed, it is essential to understand what microorganisms exist, the extent to which particular microorganisms tend to associate with one-another within a microbial community, and whether any have a tendency to be associated with metals or radionuclides. Therefore, grant applications are sought for the *in situ* analysis of individual microbes and microbial communities in soils, sediments, or groundwater, especially those microorganisms that transform or are resistant to metals and radionuclides. Proposed approaches should: (1) characterize the subtle genetic differences between species in microbial consortia and communities, and (2) determine the spatial arrangement, physiological status, and taxonomy of microorganisms. Although Bacteria and Archaea are of

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greatest interest, methods for the analysis of Eukarya will also be considered.

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

c. Real-Time, *In Situ* Measurements in Soils, Sediments, and Groundwater—The utilization of highly sensitive monitoring devices in soils, sediments and groundwater would allow for low cost field deployment in remote locations and an enhanced ability to monitor processes at finer levels of resolution. Grant applications are sought to develop sensors and systems to: (1) detect hydrogeologic and biogeochemical processes that control the transport, dispersion and transformation of contaminants (particularly metals and radionuclides) in soils, sediments or groundwater; (2) determine characteristics such as concentration, movement, or valence state of contaminants (particularly metals and radionuclides) in soils, sediments or groundwater; and/or (3) measure mass-transfer processes and rates within and among individual pores in the subsurface. Grant applications are also sought for integrated sensing and microprocessor/signal processing systems for autonomous or unattended applications of these measurements. Innovative integration of components (such as micro-machined pumps, valves, and micro-sensors) into a complete sensor package with field application in the subsurface will be considered responsive to this subtopic. However, grant applications that focus on biosensor development, will not be considered responsive and should be submitted under subtopic a.

Approaches of interest could include fiber optic, solid-state chemical, and silicon micro-machined sensors. Fiber optic sensors offer several advantages over conventional sensors including inherently high sensitivity, large dynamic range, intrinsic immunity to electromagnetic interference, geometric flexibility, and light weight. Solid-state chemical sensors and silicon micro-machined sensors also offer several advantages over conventional sensors due to their small size, relatively low cost in production quantities, linearity, and rapid response time. Substantial progress has been made in fiber optics and chemical sensing technology in the last decade; minor adaptations of readily available materials or hardware for subsurface biogeochemical analysis use, and grant applications that can not demonstrate substantial improvements over the current state-of-the-art, will not be considered responsive.

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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 enormou environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office o Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to preven pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulator compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deployin

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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 (1) the remediation of radioactive and toxic wastes to their original background levels at hundreds of DOE sites, and (2) the deactivation and decommissioning (D&D) of thousands of radiation-contaminated facilities. With regard to site remediation, long term monitoring will be required to track the migration, if any, of residual contaminants, assure the integrity of the remediation system, assure that the agreed-upon contaminant levels are maintained, and monitor the formation and/or destruction of chemical, biological, and radiological products and by-products. With regard to D&D, the mission of EM's Deactivation and Decommissioning Focus Area (DDFA) is to develop, demonstrate, and facilitate the implementation of cost-effective, safe, fast, and low risk systems to solve identified needs for D&D of DOE's radiologically contaminated surplus facilities.

The following two topics solicit grant applications for long-term monitoring technologies and the development of D&D. Each topic has subtopics providing more detailed descriptions of specific needs. An individual subtopic, accordingly, should serve as the basis and subject of a specific proposal. Background information on the DOE needs can be found on the World Wide Web (http://ost.em.doe.gov/ifd/stcg/needs.htm).

18. TECHNOLOGIES FOR LONG-TERM MONITORING OF CONTAMINANTS AT DOE SITES

The Office of Environmental Management is responsible for cleaning up the legacy of radioactive and toxic waste at contaminated sites throughout the U.S. Department of Energy nuclear weapons complex, preventing further environmental contamination, and instituting responsible environmental management. At the end of FY 1997, 60 of the 113 contaminated sites had been cleaned up. By 2006, the Environmental Management program intends to complete cleanup at most of its 53 remaining sites.

Contaminants present at Department of Energy (DOE) sites include hazardous organic compounds, metals, and radionuclides covering a wide spectrum of individual substances, matrices, and complex mixtures. The cost-effective, long-term monitoring of these hazardous materials would provide the accurate data needed to protect health and the environment. Monitoring devices and/or systems should be able to withstand representative environmental conditions and be able to operate without an external power supply for extended periods of time. **Grant applications are sought only in the following subtopics:**

a. **Integrated Site Hazard Information Systems**— Personnel at current and future environmental restoration (ER) sites require reliable, real-time hazard information concerning the potential for exposure to contaminants, including exposure from inadvertent events or intrusions to existing or previously remediated ER sites. In the current baseline approach, information about ER site hazards (e.g., multimedia contamination levels) is contained within various hard copy record files and electronic databases in centralized archives. The information is dispensed procedurally to current site workers (and, where reasonable predictions can be made, to future site workers) upon formal request to the centralized archives. Grant applications are sought to provide accurate, real-time hazard information to current site personnel, particularly such groups as emergency first responders. Of particular interest are approaches which can also extrapolate from current conditions to accurately predict future hazards to personnel.

b. **Remote Monitoring of Remediated Sites**— Monitoring of environmental legacy sites will be required for a 30 to 100 year period after the initial characterization and remediation actions are completed. The intent of such long-term surveillance and monitoring is to verify that remediation efforts have met site goals and that no unexpected contaminant releases or migrations have occurred. Typically, these long-term monitoring commitments are finalized with stakeholders and regulators upon the acceptance of the site closure plan. For some sites, the cost of long-term monitoring over decades can equal or exceed the original remediation cost. A scientific foundation is needed to support the development of new and innovative sensor systems that can significantly decrease the cost, as well as improve the performance, of this long-term environmental surveillance and monitoring requirement. Grant applications are sought to

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develop remote sensors and systems (both *in situ* and *ex situ*) for the long-term, remote monitoring of contaminants in soils, geologic formations, and groundwater at remediated sites. Contaminants of interest are radionuclides, hazardous materials (i.e., RCRA metals and organics), and mixtures of radionuclides and hazardous materials ("mixed waste").

c. Decision Theory for Achieving Cost-Effective Post-Closure Monitoring—The post-closure, long-term monitoring of once-contaminated sites that are considered to have been remediated can be very time and cost intensive. In order to judge whether a remediated site is safe, one must determine: (1) what contaminants to measure, (2) where to make measurements, (3) how frequently to make the measurements, (4) how much uncertainty can be tolerated in resulting contaminant concentrations and still adequately protect the public and the environment, and (5) how to estimate the value of new information. To answer these questions, decision theory (used along with three- and four-dimensional spatial and temporal statistical analyses and graphics techniques) offers the advantage of reducing the subjectivity associated with tolerating uncertainty: the costs of various outcomes, balanced against the probability of exceeding desired contaminant levels, are used to determine an acceptable uncertainty. In these approaches, stakeholders are engaged at every step, so that they can become an integral part of the decision making process. This immersion assures that the stakeholders not only will understand each step but also will trust the validity of the resulting long-term monitoring program design. Their involvement should ultimately be used to identify where acceptable, non-migrating contamination remains; where cost-effective monitoring should be continued to assure the absence of further migration; and what level of uncertainty is acceptable in order to conclude that the site remains safe.

Grant applications are sought to further develop the methodology for making decisions on how to design long-term monitoring programs for closed, remediated sites. Proposed approaches must address the needs for cost-effectiveness, stakeholder endorsement, and breadth of application. Approaches that employ computer-assisted decision-making are of particular interest, especially those that would allow stakeholders to easily understand how changes in key variables can alter an outcome.

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19. TECHNOLOGIES FOR DEACTIVATION AND DECOMMISSIONING

The Office of Environmental Management (EM) withi DOE is responsible for deactivation and decommissionin (D&D) of over 3,300 surplus facilities not including abo 1,700 facilities, associated with non-weapons operatior and research. In the publication, Linking Legacie (see reference 14), the DOE-EM surplus facilities are groupe into the following six process types: chemical separation component and weapons fabrication; fuel/target fabricatio reactor operations; enrichment operations; and minin milling, and refining. Another 10,000 buildings owned by th DOE offices of Defense Programs, Nuclear Energy, an environmental research will also require D&D. In additio there are 110 commercial nuclear power plants in the U.S According to current estimates, the cost of D&D for or nuclear power plant is $400 million. Clearly, the commerci nuclear sector can also benefit from breakthrough technolog advances and improvements in commercially available D&D technologies.

Deactivation refers to ceasing facility operations and placin the facility in a safe and stable condition to preve unacceptable exposure of people or the environment t radioactive or other hazardous materials until the facility ca

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be decommissioned. Typically, deactivation involves removal of fuel and stored radioactive and other hazardous materials and draining of systems. Decommissioning is the process of decontaminating or removing contaminated equipment and structures to achieve the desired end state for the facility. Desired end states include complete removal and remediation of the facility, facility entombment, release of facility for unrestricted use, or release of facility for restricted use. The subtopics below identify four problem areas that require innovative and improved D&D technologies or systems. Each of these problem areas are driven by site-specific D&D needs which can be found on individual DOE websites through links located at http://em-52.em.doe.gov/ifd/stcg.htm, or by visiting the Needs Management System at http://em-needs.em.doe.gov/Home/Entry.asp. **Grant applications are sought only in the following subtopics:**

a. Characterization of Difficult-to-Access Locations—Technologies are needed to improve the real-time characterization of radionuclides, RCRA heavy metals, and TSCA organics in facilities, equipment, and materials. The integration of improved and innovative characterization devices with decontamination and dismantlement equipment could reduce costs, minimize waste, reduce the amount of secondary waste, and lower risk to site workers. Grant applications are sought for characterization and surveying systems that can measure contamination in difficult-to-access places such as underground tanks, equipment, and piping systems. Of particular interest is the ability to detect whether the radioactivity is within site-specific release levels while correcting for high background levels of contamination, so that decontamination and material segregation processes can be enhanced. Other desired improvements include faster count times, better accuracy and precision, and increased mobility and ease of field deployment.

b. Decontamination of Surfaces—Technologies are needed to improve upon baseline decontamination processes (including mechanical, thermal, and chemical methods) to remove contamination from surfaces. Present methods are often labor intensive and may result in large quantities of solid or liquid secondary waste. Systems are needed to reduce occupational exposure, permit the reuse of a component, reduce the potential for release and uptake of radioactive materials, and facilitate waste management. Radioisotopes of primary concern are cobalt, cesium, plutonium, and uranium. Other contaminants of concern include mercury, technetium, strontium, americium, tritium and beryllium, as well as organic contaminants such as PCBs, TCE, and lead (often in the form of lead-based surface coatings and paint). Grant applications are sought for improved decontamination techniques for surfaces of stainless steel, iron, various types of structural steel, galvanized steel, and materials of construction. Of particular interest is the decontamination of gloveboxes and process piping due to their variety in size, shape, and accessibility. Opportunities also exist to develop new or significantly improved decontamination techniques for the surfaces of contaminated walls and ceilings. The decontamination methods should facilitate the recycle and reuse of both contaminated and clean-up materials. Integration of the decontamination system with real-time characterization and survey systems is also desirable.

c. Robotic Systems for Dismantlement and Size Reduction—D&D activities require technologies to improve the physical dismantling and demolition of facilities, facility internals, and process equipment. Such improvements would be expected to lower life cycle costs, lower health and safety risks to workers and the public, lower the risk of detrimental environmental impact, reduce the amount of secondary waste, convert the contamination risk into lower RCRA hazard levels and waste categories, and increase reuse of materials. Currently, much of the dismantling activities at D&D projects involve hands-on techniques, which are not only slow and expensive, but also the close contact with contaminated materials exposes workers to radiation dangers. Grant applications are sought for robotic dismantlement and size reduction systems for piping, tanks, flat stock pressure vessels, structural steel, and glove boxes. Of particular interest are systems that facilitate recycling.

d. Materials Handling for Disposal—Technologies are needed to improve baseline approaches for contaminated materials handling and disposal. Such technologies would be expected to reduce the D&D life-cycle cost by decreasing the quantity of waste generated and destined for low-level waste disposal facilities, and by promoting material recycle and reuse. Grant applications are sought for improved technologies and systems for shredding, compaction, crushing, material segregation, treatment, packaging, and waste handling. Systems should be capable of handling a wide range of contaminated material, including concrete, steel, soil, and construction materials (i.e., roofing, asphalt, asbestos, lumber, tile, lead bricks, siding, and sometimes electronic equipment). Desired systems should be semi-autonomous in order to minimize the involvement of D&D crews.

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PROGRAM AREA OVERVIEW - FOSSIL ENERGY

http://www.fe.doe.gov

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

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

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

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

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20. OIL AND GAS TECHNOLOGIES

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

a. Oil Reservoir Characterization—Grant applications are sought to develop innovative methods to characterize oil reservoirs in terms of their sedimentary facies, structural and diagenetic architectures, rock-fluid and fluid-fluid interactions, and fluid-flow properties. The objective is to determine heterogeneity and time dependent fluid flow through an oil reservoir as a result of primary to tertiary production practices. Of particular interest are reservoir characterization methods that include a combination of multiple techniques and utilize multiple data sets including 4-dimensional, 3-component seismic with log data, and (possibly) electromagnetic data.

b. Robotics for Deep Water Gas Drilling and Production—Grant applications are sought for innovative monitoring and control systems for deep water drilling operations, with emphasis on the ultra-deep (>5,000 ft) water depth environments in the Gulf of Mexico. These systems should integrate with and/or augment systems currently being investigated for deep water operations (e.g., dual-density and/or riser-less drilling systems, modular subsea production systems, etc.). Grant applications should focus on providing potential solutions to needs presented at the Drilling Engineering Association's Second Quarter 1999 Meeting under the discussion topic, "Deep Water Well Control Technology Potential Improvements." Minutes of that meeting can be found on the Internet at http://www.dea.main.com (then click on "meetings," "second quarter," and "minutes"). A general review of deep water drilling research projects can be found on the Drilling Research and Resource Assessment Project homepage at http://www.dea.main.com/DRARAP/drarap.htm.

c. Natural Gas Processing—Over the past decade, DOE' Gas Processing Program has evolved in support of ou national goal to expand the development and utilization o our abundant domestic natural gas resources. The use o natural gas offers environmental benefits over othe conventional energy sources and helps to offset increasing o imports. However, some natural gas resources contain larg amounts of nonmethane gases and natural gas liquids, whic make them uneconomical to market as natural gas. Th ability to remove the nonmethane impurities and natural ga liquids could have significant favorable economic and energ efficiency impacts. Grant applications are sought for in novative technologies to raise low-quality raw natural gas t pipeline quality by removing nitrogen, carbon dioxide, wate hydrogen sulfide, and natural gas liquids. Areas of intere include membranes, absorption/adsorption technique and/or hybrid combinations of these technologies (since suc techniques would have crosscutting applications in coal ar other fuel related areas where feed, combustion, or was streams require the removal of impurities or the need t concentrate specific components). With respect to th removal of hydrogen sulfide from natural gas, the techniqu sought must also encompass its subsequent or dire conversion to elemental sulfur or other environmental benign products. In addition, in order to show mark potential, teaming with industry for possible field testing an demonstration of these techniques is desired.

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* Available from Society of Petroleum Engineers. Telephone: 1-800-456-6863. E-mail: books@spelink.spe.org. Web Site: http://www.spe.org

** Available from the National Technical Information Service. For ordering infoprmation see Section 7.1. Also available on the Web from DOE Information Bridge at: http://www.doe.gov/bridge. Search by Report No. or NTIS Order No.

21. ADVANCED POWER SYSTEMS

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

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a. Pressurized Fluidized Bed Combustion (PFBC) Ash-Letdown Systems—Some of the more significant challenges facing the development of PFBC systems include the processing, handling, feeding, and removal of the various solids used and generated throughout the operation. Specifically, solids handling and transport difficulties associated with PFBCs hamper the reliable and consistent removal and cool-down of ash wastes from the combustor, i.e., the ash-letdown process. Significant problems are associated with existing, commercially-developed systems including pressurized lockhoppers and pneumatic conveyances. For example, lockhopper discharge valves are difficult to keep in operation due to mechanical lockups caused by thermal expansion, and the high wear rates of tight-clearance components make it difficult to maintain adequate system pressurization. Although materials are available to withstand the high temperatures typically encountered in PFBC systems, novel mechanical solutions are required to improve overall systems reliability and cost effectiveness. Grant application are sought for the development and testing of improved solids handling and transport systems for the letdown of ash from PFBCs at temperatures up to 1500-2000°F and pressures up to 500 psi into ambient temperature and pressure conditions. Innovative and cost-effective solutions for improving the operability and reliability of existing systems or the development of new systems will be considered. Proposed systems must be capable of controlling the solids flow in order to provide for optimum operation of the integrated PFBC system.

b. Advanced Integrated Gasification Combined Cycle (IGCC)—IGCC systems combine more than one energy conversion or power production technology to generate synthesis gases which in turn are used to produce energy forms such as electric power, steam, hydrogen, fuels, and chemicals. Although IGCC systems can utilize a variety of carbonaceous feedstocks, gasifiers in current systems have limited fuel flexibility and typically use a single resource. Grant applications are sought to develop advanced feed systems which are capable of co-feeding multiple fuels with disparate characteristics. The multiple-fuel mixture should consist of 10 to 40 percent low cost feedstocks mixed with the primary coal feed. Feedstocks of interest include biomass, municipal solid waste, sludge, industrial wastes such as refinery heavy oils and petroleum cokes, and lower quality coal resources such as coal wastes. The feed system must be capable of crossing the pressure barrier into a pressurized gasifier operating in the range of 300 to 500 psia. Grant applications must also address: (1) the ability of the gasifier to handle differences in heat content, particle density, particle shape factors, and moisture content; (2) new or improved feed system equipment and design; (3) consistency and repeatability in normal operation, as well as in start-up and shut-down conditions; (4) the need for corresponding high performance feed measuring instrumentation; and (5) the need to assure that the proposed feed system does not unnecessarily impede early entry, niche market commercial development.

Both wet feed systems and dry feed systems are of interest. Wet feed systems employ hydrocarbon liquids, and/or solids slurried in water, as feed materials along with the primary coal feed. In dry feed systems, the primary coal feed would be mixed with dry materials that incorporate significantly different material properties. For wet feed systems, grant applications should also address property alteration or conversion methods to assure suitability as a liquid or slurry feed. For dry feed systems, the grant applications should address equipment and processes needed to modify the alternative feed materials in order to blend them into acceptable co-mixtures. Whether wet or dry, the feed system may be employed at a single point injection site or at multiple points into the gasifier.

c. Topping Combustors and Combustion Turbine Engines for Advanced Pressurized Fluidized Bed Combustion (APFBC)—APFBC is being developed to achieve high plant efficiency and very low pollutant emissions at a competitive cost. The APFBC configuration uses gas turbines and steam turbines in a combined cycle power system. Critical to APFBC is the combustion turbine, which is the gas turbine part of the system. Since the gas turbine is the "topping cycle" portion of the combined cycle (the steam cycle forming the "bottoming" cycle), the combustor for the gas turbine in an APFBC system is referred to as the "topping combustor." Currently APFBC uses standard, modern combustion turbine technology, integrated with special topping combustors and features that allow it to operate in an APFBC system. In order to enhance competition in this area, grant applications are sought to develop novel but practical topping combustors capable of supporting stable, low-emission combustion of APFBC fuel gas with vitiated air from the circulating PFBC process. This means that the topping combustor system must be capable of using the high temperature (1400 - 1600° F) oxygen-depleted

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(about 16% oxygen) vitiated air from the PFBC exhaust as combustion air supply. The topping combustor system must also be able to use the low-Btu content (about 135 Btu/Scf), high-temperature (1400 - 1600° F) fuel gas generated in the carbonizer section of the APFBC system. The topping combustor must be designed to operate at pressures up to 500 psig and be able to operate with natural gas or propane as startup or base load fuels.

Grant applications are also sought for novel combustion turbine engine designs specific to APFBC service. Attributes of the combustion turbine specific to APFBC include collecting and exporting compressor discharge air to other parts of the APFBC system; flexible compressed air supply for repowering applications; and incorporation of materials, valves, and burners able to import and combust hot syngas and hot vitiated air from startup to full load with low NOx emissions.

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22. MATERIALS RESEARCH FOR FOSSIL ENERGY APPLICATIONS

The objective of the Fossil Energy Materials Program is to conduct research and development on materials for longer-term fossil energy applications as well as for the generic needs of various fossil fuel technologies. The focus

is on research leading to a scientific understanding of high-performance materials compatible with hostile fossil environments. The aim of exploratory research is to generate new materials, ideas and concepts, which have the potential to significantly improve the performance or cost of existing fossil systems or enable the development of new systems and capabilities. Consequently, the development of improved materials for high-temperature, high-pressure heat exchangers, high-temperature fuel cells, and advanced turbine systems (ATS) is a major objective of the program. Other materials of interest include carbon products (noted for such outstanding properties as corrosion resistance, thermal stability, high strength, etc.) that can be taken advantage of in a widening array of applications. **Grant applications are being sought only in the following subtopics:**

a. **Advanced High Temperature Alloys**—A new generation of corrosion resistant, high temperature alloys are needed as hot components in advanced fossil energy combustion and conversion systems.

So-called superalloys are usually nickel-based and are so named because of their very high strengths at high temperatures. However, nickel-based alloys are of limited value to fossil energy systems in which sulfidation is the primary degradation mode. To overcome this concern, advanced austenitic and ferritic alloys are being developed for use in the main steam lines, piping, reheat lines, valves, and superheaters and reheaters of advanced coal combustion plants, as well as in recuperators for advanced turbine systems. These iron-based alloys would be more tolerant of sulfidizing environments, but often they do not have sufficient strength for use at high temperatures. Grant applications are sought for strengthening mechanisms to enable wrought ferritic and iron-based austenitic alloys to operate at temperatures greater than 900°C. Areas of interest include both novel strengthening mechanisms as well as improvements to recently developed techniques.

Such recently developed techniques include oxide dispersion strengthening which can enhance the creep strength of promising alloys such as iron alumindes. Components made of oxide-dispersion-strengthened (ODS) alloys could allow operation at higher temperatures than possible with conventionally-strengthened alloys. However, barriers associated with joining these ODS alloys must be overcome in order to expedite their use. Therefore, grant applications are also sought for the development of novel techniques fc joining ODS alloys, compatible with operation at tem peratures greater than 900°C. The grant application mus explain why the proposed joining technique would nc disrupt the oxide dispersions in the ODS alloy and thu destroy the strengthening mechanism.

b. **Materials for Fuel Cell Applications**—Solid oxide fu cells offer a highly efficient means to convert fossil fuels t electricity. With a solid rather than a liquid electrolyte, as i molten carbonate fuel cell technology, corrosion problem are minimal and electrolyte management issues a nonexistent. High operating temperatures of 800 to 1000° offer several advantages: the fossil fuels can be reforme internal to the fuel cell, eliminating the need for an extern reformer and providing increased compactness; and hig quality heat is produced as a byproduct, which can be use for cogeneration. Among the most critical needs for th commercial deployment of solid oxide fuel cells a interconnectors that have a good thermal expansion match fuel cell components and that can be thermally cycle Present interconnectors for solid oxide fuel cell applicatio are composed of complex ceramic oxides called perovskite Metallic interconnections for solid oxide fuel cells would l desirable and could offer significant performance and co advantages. However, metallic interconnections have n been successfully deployed because (1) oxidation produc an insulating (non-conducting) surface on the metall interconnects, leading to unwanted reductions in co ductivity; and (2) there is an incompatibility in therm expansion between the metallic interconnect and electro materials. Grant applications are sought for alloys alloy/coating systems which can be used as interconnectc in solid oxide fuel cells operating at 600-1000°C, and whi overcome the above problems.

c. **Materials Repair Technology for Advanced G Turbine Systems**—Electricity generation from both natu gas and coal is projected to increase significantly in the U through the year 2015 to meet increased demand and offset the decline in electricity generation from nucle power. With the low cost of natural gas, and the relative low capital requirements for gas-fired capacity compared coal-fired capacity, natural gas is expected to nearly triple share of electricity generation. The Energy Informati Agency estimated that gas turbines ultimately would satis 81 percent of new electric power demands. The achievem of ultra-high efficiencies for gas turbine systems, along w

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a concurrent reduction in emissions, will require operation at higher temperatures and pressures. Therefore, novel materials and components will need to withstand these higher temperatures as well as the oxidation/corrosion environment of the working fluids, steam, and product gases. Just as importantly, the life extension of turbine systems will require novel methods for repair and refurbishment of critical components.

Grant applications are sought for welding techniques to treat or repair damaged or defective components in high temperature, single crystal, or directionally solidified castings of high performance alloys for advanced turbine systems. Proposed approaches should address nickel and cobalt based alloys, Directionally Solidified (DS), and Single Crystal (SC) castings, and the unique challenges posed by each. Proposed techniques could utilize either the parent metal as the welding material or a filler that meets or exceeds the parent metal properties. The resulting weld not only should be free of micro-cracking, but also should meet the strength and creep properties of the parent metal. Repaired components should meet or exceed typical aerospace requirements.

Grant applications are also sought to develop *in situ* patching techniques for thermal barrier coatings. As a first step in the development, a spot patch technique for blade and vane thermal barrier coatings (including the basecoat) should be provided. The second step is to perform this process *in situ*, requiring only a turbine cover lift.

Innovations should either contribute directly to the achievement of DOE Advanced Turbine Systems (ATS) program goals, or offer post-ATS performance enhancements.

d. Advanced Carbon Materials—Significant potential exists for meeting both current and future domestic and foreign market demand for carbon-based materials used in strategic technologies, such as gas separation, water and air purification, carbon electrodes, carbon black, and carbon fibers, whiskers, and filaments. Articles derived from carbon-based materials can be molded into intricate shapes, thus avoiding the cost of machining that is traditionally associated with metals. The use of these light-weight, strong materials could also result in increased energy efficiency, particularly in the transportation sector. More advanced carbon products such as fullerenes, metal-coated fullerenes, carbon nanotubes, carbon nanoparticles, and porous carbons appear to hold great potential in such value-added applications as catalysis, fillers and conductive additives to plastics, molecular sieves, hydrogen selective membranes, and high storage capacity (e.g., hydrogen) materials.

The required form of carbon materials needed to produce such an array of products can be derived from coal, coal tars and coal-derived liquids, but have been predominately manufactured from petroleum feedstocks due to the latter's lower heteroatom content, which results in easier processing methodologies to achieve desired product quality. However, petroleum feedstock sources are becoming more limited, requiring the carbon industry to look elsewhere for supplies of materials to meet the expanding demands. Therefore, grant applications are sought for novel, innovative concepts and processes that produce any of the aforementioned carbon materials, or precursors, from coal or coal-derived sources. Proposed concepts/processes must be economically competitive, or exhibit superior performance characteristics, to petroleum-based precursors. Grant applications are also sought: (1) to develop and demonstrate processes for producing high quality pitches from coal using light hydrogenation and solids separation; and (2) for novel coal-derived carbon products that demonstrate suitable substitution characteristics in either currently-existing commercial materials that utilize petroleum-based carbon materials, or in new products which are yet to be commercialized. In all cases, Phase 1 results should include an estimate of the process economics.

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23. HYDROGEN AND FUELS TECHNOLOGIES

Concerns about global climate change and energy security require the development of more efficient power generation and cleaner burning fuels. Hydrogen is one such fuel that, when combined with fuel ce technology, would offer opportunities in several markets i the hydrogen could be derived from liquid fuels compatibl with the existing infrastructure. Remote villages an recreation areas constitute one such market where liquid fuel are used to drive combustion driven turbogenerators. In th transportation market, the need for improved urban ai quality presents an opportunity to use hydrogen as a zer emission vehicle fuel. This would be especially attractive i the hydrogen were derived from an on-board source. (A California mandate requires that, by 2003, 10 percent of a new vehicles sold in the state have zero emissions.) Anothe area of interest is the development of processes to produc higher quality, more environmentally benign diesel fuels Diesel fuels offer higher energy efficiency and correspondingly, lower carbon dioxide production per mil driven. In the opinion of engine and vehicle manufacturers diesel fuel derived from the Fischer-Tropsch (F-T) proces will be ideal for meeting future environmental regulations Also, F-T diesel is easily integrated into the existin distribution infrastructure of the transportation secto **Grant applications are sought only in the followin subtopics:**

a. **Hydrogen Production from Carbonaceou Feedstocks**—Fuel cells use hydrogen or a hydrogen-rich ga made from another fuel. As the hydrogen delivered to th fuel cell system becomes more pure, the system becomes les capital-intensive, more energy-efficient, and requires les maintenance. One of the reasons that fuel cell systems ar not more widespread is that no large scale distributio system exists for the hydrogen they require as fuel. A extensive transportation, storage, and distribution system fc hydrogen would require a very large investment. Howeve a distribution system for one possible source of hydrogen i already in place, namely, the distribution system for gasolin and diesel fuels. To link these existing fuel distributio systems to fuel cell power plants, fuel reformers would b needed to generate high purity hydrogen from hydrocarbo fuels during intermittent demand cycles. Therefore, grar applications are sought for fuel reformers that can conve gasoline and/or diesel fuel into high purity hydrogen witho sacrificing the high efficiency power generation obtainabl from fuel cells. These units must be small and be able t operate on an intermittent basis with minimal time lag fro start up to hydrogen production. If intended for automotiv use, they must be compact and rugged enough for onboar operation.

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b. Mid-to-High Temperature Solid Oxide Fuel Cells—Solid Oxide Fuel Cells (SOFC) offer some distinct advantages compared to other fuel cell types due to the high operating temperature. For small volume, high power density applications, one of the most important advantages is the potential to convert gaseous and liquid fuels to hydrogen directly within the fuel cell stack without requiring additional volume for a processing system. However, for direct internal reforming to be feasible, two obstacles must be overcome: (1) the deposition of carbon at low steam-to-carbon ratios when steam reforming is utilized, and (2) the detrimental affect of the sulfur compounds that exist in commercial fuels. In addition, the conversion of these fuels to hydrogen in a SOFC at temperatures less than 800°C is not well characterized. Grant applications are sought to develop new or improved methods to convert gaseous and liquid fuels to hydrogen directly within a solid oxide fuel cell with negligible carbon deposition and with lifetime tolerance to commercial fuel levels of sulfur compounds. Proposed methods should be characterized experimentally so that the lowest practical operating temperature can be identified, along with other important considerations such as thermodynamic equilibrium, chemical kinetics, and safety. Practical operating temperatures as low as 550°C are desirable although new or improved methods for higher temperature operation are also acceptable. The results of the proposed effort must have practical applicability in a SOFC environment with lifetime goals of 40,000 hours for stationary applications and 10,000 hours for mobile applications, and a stack cost goal of less than $100/kW.

c. Catalyst/Wax Separation Technologies—The Fischer-Tropsch synthesis process is a candidate for the production of high quality, environmentally clean, diesel fuels. In this process, high molecular weight hydrocarbon waxes are synthesized in the slurry phase from synthesis gas. The process utilizes a fine particulate catalyst which must be separated from the waxes before the waxes are sent to a hydrocracker to obtain the desired end product that distills in the diesel boiling range. However, the efficient and complete separation of the catalyst from the high molecular weight wax has not been achieved. If the Fischer-Tropsch catalyst is carried with the hydrocarbon wax feed to the hydrocracking step, the process becomes wasteful and inefficient, and results in a potential catalyst poison downstream. Grant applications are sought for innovative methods to improve the catalyst/wax separation step that follows the slurry phase Fischer-Tropsch synthesis of high molecular weight hydrocarbon stocks before they are sent to a hydrocracker to produce diesel fuels. Areas of interest include improved catalyst formulations to render the catalyst/wax separation easier, devices or methods to improve the catalyst/wax filtration step, or novel reactor designs that enhance catalyst/wax separation.

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** See Section 7.1

PROGRAM AREA OVERVIEW - ENERGY EFFICIENCY AND RENEWABLE ENERGY

http://www.eren.doe.gov

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

It is estimated that the energy technologies and practices supported by the Energy Efficiency and Renewable Energy program hav saved Americans ten to fifteen billion dollars in energy costs over the past decade. These savings continue to mount as new energ technologies developed by the program for buildings, transportation, utilities, and industry are put to use and as research continue:

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These energy savings are accompanied by parallel reductions in the emission of pollutants that affect human health and in the production of greenhouse gases. The EE program in renewable energy has advanced the state of technologies in such areas as solar, wind, and biomass to the point where renewables have been projected to supply as much as 28 percent of the nation's energy by 2030.

24. HYDROGEN PROGRAM: ALTERNATIVE CLIMATE-FRIENDLY PROCESSES TO PRODUCE FUELS FOR FUEL CELLS

Proton Exchange Membrane (PEM) fuel cells, which offer efficient and environmentally benign power generation, require hydrogen and other low molecular weight products as fuels. Advanced production methods are needed to produce these fuels from both conventional and nonconventional feedstocks and with minimal environmental emissions. Proposed approaches should not only develop production methods but also should seek to understand the physical and chemical processes involved in the conversion of feedstocks to hydrogen and other light fuels. **Grant applications are sought only in the following subtopics:**

a. Conversion of Biomass into Hydrogen and Other PEM Fuels—Grant applications are sought to develop advanced processes for the conversion of dry biomass feedstocks into hydrogen and other appropriate fuels for PEM fuel cells. The feedstocks could include agricultural wastes and residues or biomass specifically produced for energy uses. Upstream unit operations (i.e., conversion processes to make syngas) are of the most interest as the downstream unit operations are expected to be essentially independent of feedstock. Grant applications should also describe methods for keeping adverse environmental emissions to a minimum.

b. Hydrogen Production from Moist Feedstocks—Compared to dry biomass feedstocks or solid fossil fuels, some biomass and agricultural waste materials (e.g., wet weeds and sewage sludge) have much higher moisture content and affinity for moisture. Moisture contents up to 50 percent by weight (wt%) are not uncommon. In the production of hydrogen, these feedstocks must be dried to about 15 wt% moisture to enable pyrolysis and gasification to be efficient and sustainable, and to avoid difficult materials handling problems. Grant applications are sought to develop processes for the production of hydrogen from these moist feedstocks, which avoid the drying step. Of particular interest are approaches that reduce the quantity of residual ash or inerts to levels comparable to processes that use dry biomass feedstocks. Purification technologies may be required for the end product to be acceptable for PEM fuel cell use.

c. Direct Conversion of Hydrogen from Renewable Sources—Whereas the preceding subtopics involve multi-step conversion processes for the production of hydrogen, grant applications are also sought to develop biological, thermal, chemical, or electrochemical processes that produce hydrogen directly from renewable energy sources. For example, in biological processes, microorganisms could be engineered to produce hydrogen as a waste product, or to produce it by splitting water. Thermal processes might utilize concentrated solar energy to produce hydrogen from carbon monoxide and steam. Proposed approaches should assure that adverse environmental emissions are minimized.

d. Production of Hydrogen from Fossil Fuels Using Plasma Energy—The Department of Energy (DOE) is interested in the production of hydrogen from fossil fuels, particularly natural gas, with an aim of introducing hydrogen into the transportation and utility energy sectors. By utilizing cheap fossil feedstocks, the overall economics of hydrogen use could be improved. The use of plasma energy in these processes offers the possibility of higher conversion rates due to the high plasma temperatures. Grant applications are sought to develop hydrogen production processes that incorporate the use of plasma energy in the conversion of fossil fuels, either for initiating or sustaining the reactions. As appropriate, grant applications should include the design and/or development of the necessary reactors and reactor materials. Proposed approaches should offer an energy savings in excess of 20 percent over conventionally-used methods, and have reduced levels of greenhouse gas emissions.

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25. FUEL CELLS FOR BUILDINGS

The Department of Energy (DOE) Fuel Cells for Buildings program is developing key Proton Exchange Membrane (PEM) fuel cell power system components and subsystems specific to building cogeneration applications. For fuel, these systems utilize natural gas, on which the fuel cell's reformer operates to produce a reformate with hydrogen as the key component. The fuel cell stack itself operates on the natural gas reformate and air. While considerable progress is being made in the development of fuel cells for buildings, significant advances still need to be made to improve system performance, efficiency, and cost. Components and subsystems must be consistent with the following system goals: (1) operation on natural gas; (2) heat rejection temperatures in excess of 110°C, in order to provide access to a broad range of applications for cogeneration systems and reduce the cost of heat rejection when operating in a power-only mode; (3) full load thermal-to-electrical energy efficiency of 35 percent or higher for the complete system (which includes fuel processor, fuel cell stack, power electronics, and air and thermal management), based on the higher heating value (HHV) of the fuel; (4) operation at a pressure of 1.5 atm or below; (5) simple construction with no heavily-loaded mechanical subsystems that limit operational life and reliability; (6) high reliability during long-term operation (>40,000 hrs) on natural gas reformate generated from a low-cost fuel processors; and (7) manufacturing costs that meet an overall installed system cost target of $1500/kW or less. **Grant applications are sought only in the following subtopics:**

a. Alternative Catalyst Electrode Structures—In order to meet or exceed the system level efficiency targets identified above, considerably more work needs to be done to improve the hydrogen uptake at the PEM cathode. With currently used platinum (Pt) catalysts, the loading on the cathode is only 0.15 mg Pt/cm^2, and, consequently, cathode (oxidant) stoichiometries (in the range of 2.0 to 2.5) are much larger than the anode (fuel) stoichiometries (which are approaching 1.1 to 1.2). As a result, electric current densities are limited to 0.2 to 0.3 A/cm^2 at an operating voltage of 0.8 V and at current operating temperatures of approximately 80°C. Grant applications are sought for alternative catalyst electrode structures that will increase the electric current density by a factor of three or four at a similar operating voltage, but at the higher temperatures described above. Proposed approaches should also address how such improvements would allow for reductions in both the large cathode overvoltage and the parasitic power losses associated with air management.

b. Novel Carbon Monoxide (CO) Reduction Processes—High levels of carbon monoxide (CO) concentration, in the reformate produced by the natural gas PEM fuel cell reformer, poison the Pt catalyst used in the PEM anode and degrade fuel cell performance. Current technologies for reducing the CO concentrations each have shortcomings: (1) adsorption technologies require that a portion of the purified hydrogen stream be used as a sweep gas for regenerating the adsorbent, thus reducing hydrogen yield; (2) absorption technologies require a high heat loading to reject the CO; (3) catalytic selective oxidation, a favored approach for many applications, has difficulties with response and control as well as with parasitic hydrogen consumption; and (4) methanation, used traditionally in many industries, is difficult to apply to syngases produced from partial oxidation, due to the high CO_2 concentrations. Grant applications are sought for novel devices or processes for CO clean-up that have the potential to reduce the CO level in natural gas reformate from the levels experienced today (2000 ppm) to less than 10 ppm during steady state operation and to less than 100 ppm

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during transient operation. The needed devices or processes must be efficient (i.e., low hydrogen consumption), employ relatively passive control, and be able to adapt to transient changes in operating conditions (e.g., gas mass flow rate, CO concentration, and temperature). Such devices/processes should also eliminate or reduce the need for bulk hydrogen storage to supply hydrogen to the fuel cell during transient operation. Approaches that represent revolutionary improvements over current approaches are sought.

c. Novel Oxygen Production for PEM Fuel Cells—PEM fuel cells produce electric current in proportion to the partial pressure of oxygen and hydrogen over the cathode and anode, respectively. Presently, the cheapest oxygen-containing gas mixture available for these fuel cells is ambient air. In order to improve fuel cell current density, the air must be pressurized to 2 to 3 times atmospheric pressure, which requires a costly compressor and exacts an energy cost. Grant applications are sought to separate oxygen from the air, or to enhance the oxygen concentration in air, in order to eliminate the energy penalty that results from the use of an air compressor. Such a process also should lead to substantially reduced system size and cost. Proposed approaches must allow for easy integration of the oxygen separation and/or enrichment technology into the operation of the PEM fuel cell. In addition, the partial pressure of water vapor at the cathode vent must be maintained, in order to recover water for recycling and reuse.

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26. ADVANCED TECHNOLOGY FOR GENERAL PURPOSE LIGHTING

Artificial lighting consumes about 20 percent of U.S. electric energy production. Development of more efficient light sources for general purpose illumination will significantly reduce energy use with substantial concomitant environmental benefits. The efficiency of converting electricity into visible light by commercial light sources has increased only incrementally over the last three decades. While there have been some significant recent advances, such as the compact fluorescent lamp, only rarely have revolutionary new light sources been developed. Increases in lighting efficiency have come primarily through substitution of one type of lamp with another.

The potential for increases in light source efficiency is significant. Even the most efficient of today's sources only convert about 30 percent of the electrical energy into visible light. Efficiency increases of a factor of two should be possible if major technical breakthroughs could be developed for current types of lamps (incandescent, fluorescent, and high intensity discharge types) or if entirely new concepts, such as solid state light sources, could be developed.

Grant applications are sought which address the potential for significant efficiency improvements, rather than incremental advances to existing technology. Areas of interest include basic conceptual design issues, specific materials science opportunities, or innovative device designs or packaging concepts. All grant applications must include predictions of light production efficiency and should discuss theoretical and practical limits of the subject technology. **Grant applications are sought only in the following subtopics:**

a. New Solid State Light Sources—Solid state devices may eventually revolutionize the general lighting industry with very significant and positive effects on energy consumption. This rapidly emerging technology area has primary near-term applications in displays, signs and indicators, but its applicability to general purpose lighting is uncertain. Existing solid state products such as LEDs typically operate at efficacies (measured in lumens per watt) at or below conventional incandescent lamps. Although

LEDs are considerably brighter than incandescent sources, and are therefore well suited to applications where visibility is a high priority, their inherent low efficacy preclude their widespread use for general purpose lighting. Grant applications are sought to develop solid state light sources with high efficacies for eventual use in general-purpose lighting.

b. Electrodeless Lighting—In electrodeless lamps, an enclosed gas or gas-plasma mixture is electronically excited by high frequency electromagnetic radiation (from low radio frequencies to high microwave frequencies, depending on coupling method and gas mixture). By eliminating internal electrodes, many of the current constraints on lamp design could be removed. For example, gas-plasma mixtures could be selected without concern for potential reactivity with internal electrodes, which might otherwise lead to reduced efficiencies and lifetimes of the lamp. Grant applications are sought to design and develop novel electrodeless lamps, innovative variations of existing electrodeless concepts, and/or critical electrodeless lamp components, leading to increased efficiency and longevity compared to discharge lamps. In particular, approaches are sought that will prove to be economical to manufacture and compatible with the increasingly stringent regulation of and commercial competition for frequency spectrum allocations.

c. Two-Photon Phosphors for Fluorescent Lighting—Existing efficient fluorescent lighting products typically operate with an efficacy (measured in lumens per watt) in the range of 82 to 90. While four times more efficacious than incandescent light sources, the fluorescent lamp is still only about 25 percent efficient in converting electricity into visible light. Major increases in efficacy could be achieved by increasing quantum splitting in phosphors to produce more than one visible photon for each absorbed ultraviolet photon. Grant applications are sought to develop techniques to accomplish this multi-photon production in fluorescent lighting applications. Since basic research may be required to achieve the desired results, collaboration with basic research institutions and/or applications-specific manufacturers is encouraged.

d. Improved Incandescent Lighting—A very significant fraction of lighting energy use is consumed by incandescent lamps. Existing incandescent lighting technology provides practical solutions to numerous lighting applications including many residential and decorative uses. While more efficient alternatives to the incandescent lamp are available, there may always be a need for producing light based upon the incandescence of electrically heated filaments or conductive substrates. Since visible light production by heating electrical conductors has been used since about 1850, considerable research to improve this popular process has already occurred. Nonetheless, grant applications are sought to increase the efficiency of incandescent lighting still further. To the degree practical, proposals should include sufficient historical discussion of the proposed innovation to enable competent evaluation and comparison to previous research.

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27. HYBRID ELECTRIC VEHICLE TECHNOLOGY

To support the Partnership for a New Generation of Vehicles (PNGV) program, new technologies are needed for electric motors, high voltage connectors, DC bus capacitors, and advanced sensors for future vehicles. Their development could reduce the cost, weight, and size of motors in electric and hybrid electric vehicles (EV/HEV), improve controls for energy management, increase overall power efficiency, and improve performance and driving range. **Grant applications are sought only in the following subtopics:**

a. Improved Electric Motors for Hybrid Electric Vehicle Transportation—Advances in electric motors are needed to meet joint program goals for EV/HEV auxiliary motor applications. Grant applications are sought to develop: (1) innovative noise and vibration reduction techniques for motors operating in high torque ranges, at operational voltages of 42-300 volts; (2) innovative ways to reduce the number of motor parts counts (low part counts are expected to result in lower cost motors); and/or (3) improvements in starting performance. Advancements in

induction, synchronous, switched reluctance, and permanent magnet synchronous motors will be considered. Grant applications should attempt to quantify the projected improvements in motor cost, efficiency, and power density. As a reference, the cost and power density goals for a 3-5 kW electric motor are $4/kW and 2 kW/kg, respectively. Applications must show that the technologies developed will be applicable to large volume manufacturing. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

b. Advanced Materials and Packaging Concepts for High Voltage Connectors—As a result of advancements in electric and hybrid electric vehicles, a new family of electrical connectors is required. Grant applications are sought to develop connectors for under the hood environments (-40 to 125°C) that are low cost ($15-25 per mated pair) and suitable for high voltages (42-350 volts). This new family of connectors (100A, 200A, and 300A) must provide power conductors with a 360° coaxial shield at all interfaces for the attenuation/suppression of electromagnetic interference (EMI) and with an environmental seal to withstand a 1500 psi aqueous spray wash at close range. A keying system must be provided to prevent incorrect mating of connectors in applications where multiple connectors are used in close proximity. For example, packaging concepts with three power pins and two interlock pins for three phase AC, and with two power pins and two interlock pins for DC, would be suitable. The power contacts should be capable of crimping with the power cables and/or bus bar terminations with proper voltage and creep spacing for applications up to 350 V. Bulkhead mounted connectors with the capability of replacing the dielectric/contact assembly are preferred. Grant applications should provide estimates to quantify the projected cost to manufacture in large volume. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

c. DC Bus Capacitors—Advances in EV/HEV have created new requirements for low cost, high density, highly reliable capacitors for high voltage bus applications. (The high voltage bus is part of the power inverter used to drive electrical motors in automotive applications.) Grant applications are sought to develop these automotive bus capacitors with the following specifications: (1) capacitance of 300μf, (2) voltage rating of 525 volts DC, (3) equivalent series resistance (esr) less than 3 milliohm, (4) ripple current of 100 amps rms at 10 khz, (5) operation within the temperature range -40°C to +105°C ambient, (6) fail safe reliability (or less than 1 defective part per million), and (7) production cost of $0.08/μf. In addition, the new capacitors should have a 20 percent reduction in weight and cost compared to currently available capacitors, a size of 10μf/cc, and eventual availability in production quantities by year 2005. Lastly, the capacitors should have applicability to pure electric drives, hybrid drives, or fuel cell powered vehicles.

d. Sensors—Grant applications are sought to develop low cost sensors for rotor position, current, and/or torque. All sensors must be compatible with the automotive environment, which includes high temperature and vibration.

For rotor position sensors, approaches are sought that combine the position sensing function with the bearing. These bearing-integrated rotor position sensors would be an important part of high performance AC motor drives for EV/HEV applications and could also lead to important cost savings and size reduction of the motor. Even motors that were not initially designed for closed loop, variable speed operation could be easily equipped with such a sensor. The sensors should have 2 to 5 channels, absolute and/or relative output format, a digital output range of 0 to 5 volts, and a maximum speed of 18,000 rpm. The cost target is $20 to $30 above the bearing's cost. One possible candidate for this application would be a bearing-type incremental position sensor in combination with a Hall-effect sensor. Resolver-type position/speed sensors are not considered suitable for this application due to their high cost, and special mounting requirements.

For current sensing, quality optical sensors are required for the operation of current-controlled drives for feedback and protection purposes. Optical current sensors would also be expected to provide size reduction together and noise immunity improvements. In turn, size reduction (along with the attendant reduction in cost) could lead to the integration of the current sensors with power electronics packages. Proposed approaches must demonstrate AC/DC capability at 200, 400, and 600 amp, low output offset, and 100 kHz bandwidth with 0.1-0.5 percent accuracy.

The torque sensor should provide feedback to the motor controller and improve its transient response. The information would allow for command adjustments to the motor so that the shaft output closely follows the input

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command of the motor controller, independent of motor manufacturing tolerances and temperature. The torque sensor must provide a linearized shaft torque output of the electrical motors, be low cost and non-contact, have a bandwidth of approximately 500 Hz, and be accurate to within 1-2 percent. The torque measurement range is ±300 Nm before gearbox and ±2000 Nm after gearbox. Other important criteria include the ease of incorporation before and after the gearbox, and the ease of interfacing with the motor controller.

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28. BIOPRODUCTS AND BIOENERGY RESEARCH

Our most abundant natural resource, energy from sunlight, offers the opportunity to utilize a sustainable source of raw materials -- namely, biomass from our nation's crops, forestry, and agricultural wastes -- to power our homes, fuel our vehicles, and create everyday products. The use of biomass to produce BioProducts and BioEnergy (BioP&E) will help strengthen U.S. energy security, protect the environment, reduce greenhouse gases, and revitalize rural America. The Office of Energy Efficiency and Renewable Energy, including the Offices of Transportation, Industrial, and Power Technologies, seeks technologies that enable bio-based renewable resources to produce home-grown transportation fuels with low-emissions; produce commodity chemicals and other traditionally high-volume materials or consumer products; and generate clean, locally-based power. This topic is focused on discovering new technologies, or adapting existing ones, for energy efficient separation systems and catalysts used in the production of chemicals and fuels, and for agricultural residue-based feedstocks that will produce performance materials or generate clean energy for the 21st century. Grant applications must demonstrate that proposed approaches have the potential to be more economical than currently practiced technologies. **Grant applications are sought only in the following subtopics:**

a. Energy Efficient Separations for BioP&E—The processing of bio-based renewable resources to make chemicals and fuels requires improved separations technology to save energy, improve product yields, and decrease waste. Grant applications are sought to develop separations systems for bio-based renewable processes that will: (1) provide significant energy savings compared to conventional separation processes; and/or (2) improve product yield and reduce waste generation.

b. Energy Efficient Catalysis for BioP&E—Improved catalytic systems for the processing of renewables to make chemicals and fuels also offer significant opportunities to save energy, improve product yields, decrease by-product production, and decrease waste. Grant applications are sought to discover or modify enzymes and/or develop new catalytic systems that will (1) increase the yields and rates of bioprocesses, and/or (2) allow the use of lower cos feedstocks or alternative bioprocessing reaction media.

c. Energy Efficient Power Generation—Power generatic in remote off-grid locations from a diverse set of low cos locally generated waste offers an opportunity to save energ and reduce greenhouse gas emissions. Grant applications a sought to develop novel materials technologies for th modification of renewable feedstocks and/or agricultur residues in order to maximize the diversity of fuels availab for rural power generation. Grant applications are als sought to develop machinery or equipment for th mechanized handling of these biomaterials for the generatic of rural power.

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on the Web at: http://www.oit.doe.gov/agriculture/pdfs/ag25942.pdf)

29. OCEAN CURRENT ENERGY CAPTURE

The world's oceans are a potential source for clean, renewable electric power generation. Previous efforts to generate power from the oceans have been largely focused either on ocean thermal energy conversion or wave/tidal energy. Neither of these approaches has been able to overcome the technical challenges required for the development of commercially viable electric power generation systems. However, little attention has been given to evaluating the potential use of ocean currents for electric power generation. Because these currents are not intermittent and are seasonally stable, systems based on ocean currents could conceivably generate baseload power. In locations where significant currents are in close proximity to load centers, large quantities of baseload power potentially could be supplied via undersea power transmission systems. Such systems could be located well below the water's surface, reducing the potential for damage to the system or for interference with marine operations. Furthermore, the relatively low current speeds imply correspondingly low operating speeds for the undersea systems, minimizing the potential for injury to fish or marine mammals; other environmental effects are expected to be minimal. **Grant applications are sought only in the following subtopic:**

a. Electric Power Generation From Ocean Currents—While ocean currents contain substantial amounts of energy, most have been considered to flow too slowly for power generation. In recent years, significant advances in wind energy technology have led to design concepts that have dramatically improved the performance and long-term reliability of wind energy conversion systems. Since wind is fundamentally analogous to ocean currents in many respects, advanced wind energy technology may enable the development of cost-effective systems for power generation from ocean currents. Because of the high density of water relative to air, the potential for energy capture is high despite the ocean's relatively low current speeds.

Grant applications are sought for functional, robust, innovative design concepts for cost-effective electric power generation from ocean currents. Approaches of interest include those that build on advances in wind energy conversion systems, as well as entirely new approaches. Proposed projects should demonstrate the feasibility of the proposed system and provide information on system design, power transmission, system control, operations and maintenance strategies, capacity factor, capital and life cycle costs, and projected energy costs. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

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30. THERMOPHOTOVOLTAICS

Photovoltaic (PV) systems do not produce noise, toxic-gas emissions, or greenhouse gases; therefore, they have distinct environmental advantages over conventional technologies for electricity generation. Thermophotovoltaics (TPV), a related technology that generates electric power from solar cells operating in the infrared part of the spectrum, is also expected to conform to stringent environmental standards. These systems use fossil fuel-fired radiators (usually with propane) to illuminate and energize photovoltaic cells. TPV systems fall into one of two categories: (1) systems that use relatively low-bandgap materials, e.g., GaSb (0.72 eV) and InGaAs (0.36-1.42 eV) matched to gray-bodies at temperatures of 1200-1500°C, and (2) systems that use high-efficiency float-zone silicon cells matched to very

high-temperature (up to 2000°C) selective emitters. The development and production of these systems require advances in materials, manufacturing, and sensors and controls. Only those grant applications that represent major advancements in the technology while conforming to health, safety, and environmental standards will be considered. **Grant applications are sought only in the following subtopics:**

a. Thermophotovoltaic Materials for Gray-Body Emitters—For gray-body emitters, the power density spectrum has maximum value at a wavelength that increases as the temperature decreases. For mechanical reasons, it is desirable to operate gray-body TPV systems at moderate temperatures, and research shows that semiconductors in the 0.5-0.7 eV bandgap range allow a good trade-off between radiator/bandgap optical match and photovoltaic cell efficiency. Grant applications are sought to identify candidate narrow bandgap semiconductors, suitable to gray-body emitters, and associated inexpensive photovoltaic cell manufacturing processes. Binary compounds of Sn and Te, deposited by inexpensive MOCVD processes, are among the candidates for such narrow bandgap materials.

b. Manufacturing of TPV Selective Emitters—Selective emitters have the characteristic of radiating most of their power at one strong emission wavelength. Such emitters have been made from ytterbia (ytterbium oxide) for optical matching to silicon. They radiate at a single wavelength whose energy is just above the silicon bandgap (1.12 eV). Unlike gray-bodies, the position of the peak value in the power density curve is not dependent on temperature, although the height of the peak is temperature-dependent. Consequently, because of the relatively small area under the emission peak in the power density spectrum, selective emitters must operate at very high temperatures to achieve significant power emission. Unfortunately, the radiating elements (sometimes called mantles) for selective emitters are difficult to manufacture and are susceptible to early mechanical failure due to high-temperature cycling. Grant applications are to develop processes for manufacturing high-temperature TPV selective emitters with improved mechanical stability.

c. PV Cell Array Configuration for TPV—A thermophotovoltaic emitter illuminates a collector surface that has a fixed and limited area covered with PV cells. In order to maximize system efficiency, it is very important that the collector surface has maximum coverage with PV cells s that all of the available illumination is used for P conversion and is not wasted. Additionally, the arra "packaging" must accommodate thermal management an electrical interconnections. When the TPV system is used i emergency equipment, high reliability is very desirable however, conventional reliability methods, such as by-pas diode protection, sacrifice valuable collector area. Finally cell array topography must be matched to the unevei radiation profile of the emitter, so that the series strings o collector cells are uniformly matched. Grant applications ar sought for innovative methods for packaging TPV cell array in order to optimize the configuration with respect to th above issues. Proposed approaches should be developed i parallel with low-cost manufacturing techniques to assur optimal system performance at an affordable price.

d. Development of Sensors and Controls for PV an TPV Manufacturing—PV and TPV module manufacturin involves semiconductor-based technologies that depends o highly sophisticated material processing techniques. Fc example, PV processing includes such high temperatur (from 250° to over 1000°C) steps as silicon crystal growt and thin film deposition of $CuInSe_2$, CdTe, or Si. Th optoelectronic properties of PV and TPV materials are highl sensitive to processing conditions. Process specification must be maintained within narrow ranges and process yiel is very sensitive to temperature and other variations. Cos can be unacceptably high if yield is not adequate. Therefor monitoring sensors and feedback controls are essential fc improving process yields in commercial PV and TP component manufacturing. In addition to manufacturin controls, advanced PV and TPV technologies requi substantial investment in new sensors and controls in the development stages. For example, sensors designed fc silicon often are not usable for new PV materials (e.g $CuInSe_2$, CuInGsSe, CdTe) and TPV materials.

Grant applications are sought to develop improved senso and controls for TPV module manufacturing in order t evaluate and control work in process, apply statistic processes, manage product quality, and monitor and contr both material flow and ultimate product yield. Of particul interest are approaches that would also be applicable to particular PV technology (e.g., flexible thin-film P modules). It is intended that these new sensors and/c controls will (1) support improved manufacturing in re time on existing or new manufacturing lines, (2) facilita

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flexible manufacturing and allow handling of larger and thinner components (e.g., silicon wafers less than 200 microns-thick), and (3) contribute to lower production costs and environmental friendliness for future PV and TPV manufacturing. Grant applications must demonstrate knowledge of sensors currently used in PV and TPV manufacturing and their limitations or deficiencies, as well as address the expected capabilities and benefits of proposed sensors and controls. Furthermore, grant applications must include specific plans for testing the developed sensors and controls in PV and/or TPV manufacturing environments Phase II.

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PROGRAM AREA OVERVIEW - NONPROLIFERATION AND NATIONAL SECURITY

http://www.nn.doe.gov

The Nonproliferation and National Security (NN) program conducts applied research, development, testing, and evaluation of science and technology for strengthening the U.S. response to threats to national security and world peace posed by the proliferation of nuclear, biological, and chemical weapons and special nuclear materials. Activities center on the development, design, and production of operational sensor systems needed for proliferation detection, treaty monitoring, and nuclear warhead dismantlement. In addition, research and development activities are pursued to counter nuclear smuggling and terrorism.

The specific NN objectives are to: (1) develop and demonstrate technologies to detect the early stages of proliferant nations' weapons development programs; (2) develop and demonstrate technologies to detect and deter the diversion and smuggling of nuclear weapons, components, and special nuclear materials in non-cooperative environments; (3) address the detection and

mitigation of biological and chemical weapons during a domestic incident by modifying and applying technologies developed for nuclear non-proliferation and by exploiting DOE expertise in the biological and chemical sciences and in the Human Genome Project; (4) provide the U.S. Government with sensor technology, needed to monitor and verify nuclear treaties, by detecting, locating, identifying, and characterizing nuclear explosions underground, underwater, in the atmosphere, and in space; (5) develop and demonstrate technologies for nuclear materials protection, control, and accounting and for the monitoring of nuclear warhead dismantlement; and (6) exploit emerging technology to maintain the capability required to address emanating threats and other future needs.

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

31. ADVANCED SENSORS AND DATA ANALYSIS TECHNIQUES FOR NATIONAL SECURITY APPLICATIONS

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

a. Sampling Technologies for Micro-Analytical Instruments—With the advent of micro-technologies, chemical analytical instrumentation is moving closer to becoming truly hand-held and near real-time. Much attention is being given to the selectivity and sensitivity of these devices, and great strides are being made. Accompanying this progress is the recognition that new sampling methodologies are essential. Conventional sampling methodology is often cumbersome and results in loss of much of the advantage of having a hand-held instrument. Challenges include the need for precise manipulation of very small quantities of gas and liquid samples, control of particulate to avoid fouling and plugging, and assurance that the extremely small quantity of gas or liquid taken into the device is representative of the larger sample from which it is pulled. Grant applications are sought for truly innovative, yet practical, technologies for introducing statistically meaningful gas and liquid samples into micro-analytical devices in a manner consistent with the overall goals of hand-held devices that produce near-real-time results. Sustained use over many duty cycles is desirable.

b. Advanced Research in Support of Nuclear Explosion Monitoring—The DOE is responsible for research and development necessary to provide the U.S. Government with the capabilities to monitor nuclear explosions. Grant applications are sought for the development of innovative technologies, including algorithms, hardware, and software, for (1) improved event characterization, (2) enhanced detection, and/or (3) data fusion and exploitation. Grant applications should demonstrate that proposed approaches will complement ongoing or completed work (see http://www.ctbt.rnd.doe.gov/coordination) and improve capabilities to detect, locate, identify, and characterize nuclear explosions at required threshold and confidence levels in a cost-effective manner. Grant applications should focus on the advancement of seismic, hydroacoustic, and infrasound technologies.

Event characterization is the identification and location of nuclear explosions and includes the ability to discriminate these explosions from non-relevant events such as earthquakes and other man-made events. Accuracy in event characterization depends on regional studies that provide high-quality ground truth information (geology, meteorological conditions, data on man-made events, etc.) and/or seismic wave propagation information that allow the prediction of travel times and/or amplitudes. Any proposed modeling effort should be strongly tied to regional data from

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studies or should demonstrate applicability to a particular geophysically distinct region.

Enhanced detection includes the development of innovative sensor designs and/or signal-processing techniques that significantly improve signal-to-noise ratios or improve detection where low signal-to-noise ratios exist. Sensors must be compact, inexpensive, easily manufactured, reliable under adverse conditions, robust, simple to maintain, and have low power requirements.

Data fusion and exploitation refers to the ability to extract useful information from large volumes of multi-technology data. Approaches of interest include techniques for cross-technology data fusion as well as innovative techniques for accessing, viewing, and interacting with large volumes of data.

c. Biological Detection—Novel technologies are needed for detecting biological agents in air and liquid samples. Grant applications are sought to develop such technologies for ultimate use in detectors with rapid response times (minutes or less), high selectivity (to allow discrimination between the pathogens of interest and common background interferents), high sensitivity, with cost and size commensurate with the capability of the system. Although all classes of biological threat agents are of interest, submissions targeted at a single class of agents will also be considered.

d. Advanced Materials for Room Temperature Gamma Spectroscopy—Present high-resolution gamma-ray spectrometers, such as those using high purity germanium (HPGe) as the detector material, require liquid nitrogen or mechanical coolers for cooling the detector material. However, the use of liquid nitrogen causes logistical difficulties in some scenarios, and mechanical coolers (including thermoelectric coolers) may not be adequate or require too much power for some field applications. A number of companies, universities, and national laboratories have been working to develop a room temperature material, cadmium-zinc-telluride (CdZnTe), for the detection of gamma-rays. Although this material offers improved resolution over the commonly used room temperature detector material, sodium-iodide (NaI), manufacturing yields for CdZnTe devices has been limited to 1-4 percent. Although some have claimed higher yields, significant breakthroughs are needed before success can be claimed. Therefore, grant applications are sought to develop materials for room temperature gamma spectroscopy with the capability of detecting and resolving high-energy gamma radiation out to 3 Million electron Volts (MeV). Proposed efforts must demonstrate significant improvement in resolution over NaI — the ultimate goal is a resolution approaching that of cooled high purity germanium. Phase I should demonstrate proof of principle, and Phase II should result in the demonstration of the material as a gamma ray spectrometer. Proposals could focus on either new materials or on a major breakthrough in the growth of CdZnTe.

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32. ENABLING TECHNOLOGIES FOR ACTIVE OPTICAL REMOTE SENSOR SYSTEMS

The United States Department of Energy (DOE) is developing active optical systems for the study of airborne chemicals. These systems use lidar technology, in which laser pulses interrogate the environment and specialized detectors examine the return pulse, for the remote detection of these chemicals from aircraft and other platforms. Improvements in certain critical optical components is necessary for the construction of rugged, lightweight, small, power-efficient, and effective systems. **Grant applications are sought only in the following subtopics:**

a. Detector Technology Development—The focal plane array (FPA) is the technology of choice for lidar detectors, and developments are needed in several areas:

Gated detectors, which operate within very narrow time windows, are often required for active remote sensing because they can be coordinated with the arrival of the return pulse. Of particular interest are detectors that operate from the near ultraviolet (UV) to the blue-green spectral region. The only practical option presently in use for this purpose is an intensified charged coupled device (CCD) array. However, CCD arrays suffer from limitations in the detector quantum efficiency. Grant applications are sought to develop novel gating techniques for array detectors which have gating on the order of 100 nanoseconds, and also have high quantum efficiency in the spectral region between the near-UV and the blue-green (i.e., much higher quantum efficiency than backthinned intensified CCD arrays).

Grant applications are also sought to improve detector capabilities of focal plane arrays in the long-wave infrared (LWIR) and mid-wave infrared (MWIR) regions. Proposed arrays must have randomly accessible windowing and low noise, preferably less than 20 electrons; a variable, short integration time, 20 to 200 nanoseconds; windowing to a small set of pixels, for example, 1 to 100 pixels/window with 1 window/output with as many as 32 outputs; random access positioning of the window(s) to any desired area of the FPA; window frame rates of 100 kHz or greater; and an architecture suitable for hybridization to existing, standard 512 x 512 or 640 x 480 mercury-cadmium-telluride (HgCdTe) detector array designs. Such an array might be used, for example, in a receiver design for an active system that incorporates a cryogenically cooled dispersive grating spectrometer for filtering the background photon flux. This would require a large format detector array, 500 to 2000 pixels in a row and several rows wide.

Mercury-cadmium-telluride (HgCdTe) is the material of choice for long-wave infrared detector arrays. Unfortunately, the demanding specifications for uniformity and performance lead to low production yields. In order to increase production yield and lower cost, grant applications are sought for novel techniques for bonding multiple small arrays in a given pattern to achieve large arrays. For example, four separate 160 x 120 arrays could be combined to make a single 640 x 120 array. This would improve the yield since smaller arrays have a lower probability of having a defective detector. Such an arrangement would also allow for further optimization; in the above example, the four array segments could have different cutoff wavelengths to achieve better overall performance.

b. Long-wave Infrared Laser Material Development—A key technology area for long-wave infrared (LWIR) sensors is the development of new transmitter capabilities. Currently, the most robust LWIR systems use CO_2 lasers. To advance the capabilities for interrogating the environment in the LWIR region, improvements in the capabilities of CO lasers are needed in the near term and, in the long term, new types of long wave transmitters are needed. A major block to the improvement of lasers for the LWIR spectral band is directly related to materials available for components of the lasers.

Acousto-optic (AO) devices are used to tune CO_2 lasers, yet few suitable materials are available for these devices in the 8-12 μm wavelength regime. Germanium (Ge) is used most often; however it has high optical absorption and large temperature dependency of both absorption and index of refraction, giving rise to significant thermal lensing at average to high laser power. This limits the performance of Ge devices, particularly for intracavity use in lasers, where the power is highest. Grant applications are sought to develop improved AO tuners using either novel materials or

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more established materials (such as Ge) to alleviate the material limitations described above. The following characteristics are desired: high duty factor operation (>50%), high rate (~100 kHz or more), high resolution, high diffraction efficiency, high transmission, and low thermal beam distortion.

Future LWIR lidars will depend on the development of randomly- and continuously-tunable laser systems. Currently, cascaded non-linear devices (such as multi-stage Optical Parametric Oscillators) have reached a maturity level where they could be used as LWIR laser sources; however, their complexity and fragility limits their use in harsh environments such as aircraft. Grant applications are sought to develop less complex, hardened LWIR laser sources with high tuning rates and narrow line widths which can operate in an efficient, compact unit. Laser materials with low phonon energy (such as ZnSe, CdSe, $CaGa_2$, and KPb_2Cl_5) that contain either transition metal ions (Fe, Cr, etc.) or rare-earth ions (Er, Ho, etc.) as the optically active site may be important materials for consideration. These materials typically operate in the MWIR and would be interesting as less complex pump sources for non-linear processes to reach the LWIR.

c. Quantum Cascade Laser Development—Long-wave infrared (LWIR) light sources could be improved by developing Quantum Cascade (QC) lasers explicitly for use in lidar systems. Commercial sources for both QC lasers and their low noise power sources, explicitly designed for use in LWIR lidar systems, do not exist. Therefore, grant applications are sought to develop QC lasers that are explicitly designed for application in LWIR lidars. Applicants should address one or both of two possible approaches: (1) using the QC laser to seed weak lines of a CO_2 laser, and (2) using the QC lasers as direct sources of LWIR radiation. Proposed efforts must demonstrate that the QC laser can produce lasing at any arbitrary wavelength within the LWIR band at significantly increased power output compared with current QC lasers being developed for communication purposes. Projects must also include the development of an appropriate low noise power source needed to run the QC laser.

d. Ultraviolet (UV) Laser Development—Grant applications are sought to develop an ultraviolet (UV) laser which is rugged, compact, and has a high efficiency with an output wavelength near 250 nm (+/- 3 nm) and a line width of no more than 4 cm^{-1}. Beam divergence must be less than or equal to 0.5 mrad. The laser may be pulsed or continuous wave, with a minimum power of 100 mW. If pulsed, the laser's repetition rate is not critical, although a repetition rate greater than 1 kHz, with low pulse energy, would be preferable. The laser head should weigh less than 5 pounds and have a footprint less than 1 ft^2. The power supply size should be less than 1 ft^3. There should be no special cooling requirements beyond what can be achieved with a liquid-to-air heat exchanger for the laser head and an air-to-air exchanger for the power supply. The total power consumption should be less than 300 W.

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* Available from the International Society for Optical Engineering (SPIE). Telephone: 360-676-3290 Fax: 360-676-1445 E-mail: customer_service@spie.org Web site: http://www.spie.org

33. ENABLING TECHNOLOGIES FOR PASSIVE OPTICAL REMOTE SENSOR SYSTEMS

The Department of Energy (DOE) is also developing passive optical sensor technology for the remote detection of airborne chemicals from aircraft and other platforms. Passive systems examine the optical spectra emitted from the environment itself. As prototype systems move closer to being operated on airborne platforms, the development of critical optical components, as well as algorithms to process collected data, is necessary for the construction of rugged, lightweight, small, power-efficient, and effective systems. **Grant applications are sought only in the following subtopics:**

a. Tunable Gratings—Correlation spectroscopy is a method used to identify environmental chemical composition by comparing an unknown environmental spectrum with reference spectra, thereby eliminating the need to use chemical reference cells. The advent of microelectromechanical systems (MEMS) has allowed the development of real-time electrically deformable mirrors (tunable gratings), which are needed to form real-time, synthetic, infrared spectra for correlation spectroscopic systems. Grant applications are sought to build long-wave infrared (LWIR) tunable gratings for correlation spectroscopy that operate at wave numbers between 750 and 1250 cm^{-1} with a resolution of 1 cm^{-1} or better. The Phase I effort should perform risk reduction experiments and create a detailed design. Phase II should fabricate a breadboard device and test its operating characteristics.

b. Lightweight Mirrors—Platforms such as aircraft and satellites place severe restrictions on the size, weight, power, and complexity of optical detection systems. Optical components which can reduce the overall support demands of remote sensing systems could make significant contributions toward cost reduction and/or improved system performance. Current needs include the construction of meter-class, portable, non-obscuring, off-axis telescopes with low astigmatism. This would require the construction of folded telescope designs using two or three anastigmatic mirrors with relatively small f-numbers (f/ 3.5). Although current precision mirrors made with composite laminates yield superb surface finish for low scattering, they contain figure errors, especially astigmatism. Grant applications are sought for new construction methods to build inexpensive, strong, lightweight mirrors that are largely free from astigmatic errors. The ultimate objective is to field telescope designs with diffraction-limited performance and with minimum scattering in the infrared. Approaches of interest include two methods that have been identified as viable routes to achieve optical figures and finishes for ultra-lightweight but strong telescopic systems: (1) optical replication and (2) spin casting of large molded or composite structures. Phase I should demonstrate that the proposed method can produce high quality composite or molded

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mirrors of 30 cm diameter, off-axis, parabolic optics. Phase II should demonstrate the actual construction of 1 meter class apertures for the primary mirror. The mirror production should be scalable for the ultimate production of multiple mirrors and components for 10 full sets of 1-m size, anastigmatic, off-axis telescopes.

c. Fabry-Perot Filters—Fabry-Perot filters are candidates for hyperspectral, long-wave infrared (LWIR) spectrometers. Currently available LWIR Fabry-Perot filters provide 5 cm^{-1} resolution across a 2-3 micron window. However, these devices are tuned by piezo-electric tuning elements and their tuning rate is limited to approximately 100Hz. Grant applications are sought to develop Fabry-Perot filters that have tuning rates within the 1kHz to 100kHz range to speed up the repetition rate for imaging passive sensors. Filter transmission must be greater than 50 percent. Possible approaches include: (1) operation in a scanning mode, whereby the plates of the Fabry-Perot filter are in continuous motion and data is taken as the wavelengths of interest are scanned. This would require an alignment control system that could maintain parallelism of the plates while they are in motion. Alternatively, (2) liquid crystal technology, which uses an electric field to change the dielectric constant of the liquid crystal between fixed plates, may be a potential solution. This would allow random wavelength tuning limited only by the capacitance of the device. For both (1) and (2), current devices are available in the visible wavelength, regime and extensions to LWIR are needed.

d. Chemical Analysis Algorithms that Suppress Background Clutter in Hyperspectral Imagery—Variations in the ground radiance, as detected from pixel-to-pixel, is the dominate source of interference in high-resolution, mid-wave infrared (MWIR) and long-wave infrared (LWIR), hyperspectral images. Not only do these variations act as interfering clutter which must be suppressed, they also modify the very subtle signatures of airborne gases, interfering with their detection, identification and quantification. This can be shown by the following simplified equation for the radiance when an optically thin gas concentration fills the field of view of the imager:

$$N = \varepsilon_g S(k,T_g)\,\tau_a\,\tau_p + N_a + \varepsilon_p S(k,T_p)\,\tau_a,$$

where ε_g and ε_p are the ground and gas emissivities, respectively; S(k,T), the Planck function, is a spectral function of wave number, k, and temperature, T; $\tau_p = 1 - \varepsilon_p$ is the gas transmittance; and N_a and τ_a are the atmospheric radiance and transmittance, respectively. With no gas in the field of view, $\varepsilon_p = 0$, and

$$N_o = \varepsilon_g S(k,T_g)\,\tau_a + N_a.$$

Therefore, the contrast signature between the radiances with and without the gas is:

$$\Delta N = N - N_o = \tau_a \varepsilon_p [S(k,T_p) - \varepsilon_g S(k,T_g)].$$

It can be seen that the gas contrast signature is altered by the atmospheric transmittance, the ground emissivity, and the Planck function at two temperatures. These functions vary with wave number, as well as position on the ground. Grant applications are sought to develop algorithms that suppress the variations in the ground radiance and account for contrast signature modifications due to this background clutter. These algorithms must also be compatible with atmospheric transmittance and radiance corrections. Approaches of interest include variations on those that have been considered in the past (including Multivariate Linear Regression Analysis, Change Detection, Multivariate Matched Filters, Orthogonal Subspace Projection, and combinations of these approaches) as well completely novel concepts.

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PROGRAM 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 determines the essential physical characteristics of the universe. It has been long understood that atomic nuclei can be described as a collection of nucleons (protons and neutrons) which are bound together by the mechanism of exchange of subatomic particles called mesons. The research forefront in nuclear physics now requires incorporation of the quark substructure of the nucleon into the understanding of nuclear structure. Quarks, which are the most elemental building blocks of matter, are bound together in groups of three by exchange of gluons to form nucleons.

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

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

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34. NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

The Department of Energy (DOE) seeks innovative and novel approaches to technical problems encountered in basic research in nuclear physics. Measurements in this field are performed typically at the limit of technical feasibility. Hence, new capability will often generate important advances in scientific knowledge. The DOE is particularly interested in supporting projects that may lead to advances in target and detection systems for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art and outside the usual scope of research and development activities at the nuclear physics national accelerator facilities. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

a. Detectors, Detector Materials and Targets—Nuclear physics research has a need for devices for detecting and analyzing charged particles, neutrons, photons, and single atoms with improved energy, position and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, and background suppression. These devices include: solid-state devices such as silicon strip and silicon drift detectors; photosensitive devices such as photodiodes, avalanche photodiodes, hybrid photomultiplier devices, single and multi anode photomultiplier tubes, and other novel photon detectors; detectors utilizing CsI photocathodes for Cherenkov and UV light detection, and the development of new types of large area photoemissive materials such as solid, liquid, or gas photocathodes; micro-channel plates; gas-filled detectors such as proportional, drift, streamer, Cherenkov, micro-strip, gas electron multiplier detectors, and straw drift tube chambers; liquid argon and xenon ionization chambers; single-atom detectors using laser techniques; particle polarization detectors; and magnetic spectrometer components and systems. Grant applications are sought to develop: (1) thicker (more than one mm) segmented silicon charged particle and x-ray detectors and associated compact (high density), high resolution electronics; (2) very high resolution particle detectors or bolometers based on semiconductor materials and cryogenic techniques; (3) cost-effective production of n-type and p-type silicon drift chambers with active areas > 16 cm^2; (4) detectors with high position resolution, high radiation hardness, small surface temperature gradients, and integrated calibration systems; (5) high precision, low-cost, time of flight detectors; (6) efficient polarization-analyzing materials; and (7) large area image intensified systems such as those using carbon coupled devices, pixilated avalanche photodiodes, or PIN photodiodes, for use in single photon counting image reconstruction.

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

b. Scintillators and Associated Materials—Grant applications are sought for research and development of new scintillators and associated materials. Areas of interest include new heavy crystals or glasses which can serve as scintillators; Cherenkov materials for electromagnetic calorimeter applications; Cherenkov radiator materials with indices of refraction up to 1.10 or greater with good optical transparency; stable calorimeter materials in single block lengths (up to 20 radiation lengths) which could be produced in large quantities and at low cost; and composite materials with high radiation resistance.

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

c. Electronics Instrumentation and Systems—Grant applications are sought for special purpose, custom designed integrated circuits and for circuits and systems for rapidly processing data from highly segmented, position-sensitive

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Ge 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. Representative circuits include low noise preamplifiers, amplifiers, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude convertors. Compatibility with one of the widely used module interconnection standards (e.g., CAMAC, FASTBUS, or VMEbus) is highly desirable, as would be low power consumption, advanced packaging, and/or adaptability to a large number of multiple channels. Readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample and hold integrated circuits, are also of interest.

Grant applications are also sought for improved or advanced devices and systems to be used in conjunction with the above electronic circuits and systems. Areas of interest include bus systems, data links, event handlers, multiple processors, and fast buffered time and analog digitizers, as well as generalized software and hardware packages with improved graphic and visualization capabilities for the acquisition and analysis of data specifically addressing needs related to nuclear physics research and development.

d. Data Management—Large scale data storage and processing systems are needed to store, retrieve, and process data from experiments conducted at the Brookhaven National Laboratory's Relativistic Heavy Ion Collider and the Thomas Jefferson National Accelerator Facility. These data, produced at rates of 100 MB/sec or more, result in the annual production of data sets on the order of several hundred Terabytes. Similar data management systems are required to support the needs for non-accelerator nuclear physics experiments. Grant applications are sought for hardware and software techniques to improve the effectiveness and reduce costs of handling such large data volumes.

Grant applications are also sought for research and development of software systems to facilitate the handling, management, and dissemination of compiled and evaluated nuclear data.

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35. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

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

a. Materials and Components for Radio Frequency Devices—Grant applications are sought for research and development leading to improved or advanced superconducting and room temperature materials or components for radio frequency (rf) devices used in particle accelerators. Areas of interest include: (1) peripheral components such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, and magnetostrictive cavity tuning mechanisms; (2) termination materials for use at 2 to 4 K, compatible with the ultra high vacuum and dustfree environment, and capable of absorbing microwaves efficiently from 2 to 90 Ghz; (3) methods to avoid inclusions in the superconducting material and contamination on the surface of the superconductor; and (4) innovative designs for hermetically sealed refrigerators and other cryogenic equipment that simplify procedures and reduce costs associated with reparability and modification.

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

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

c. Particle Beam Sources and Techniques—Grant applications are sought to develop: (1) particle beam ion sources with improved intensity, emittance, and range of

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

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

d. Accelerator Control and Diagnostics—Grant applications are sought for "intelligent" software and hardware to facilitate the improved control and optimization of charged particle accelerators and associated components for nuclear physics research. Developments that offer generic solutions to problems in the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning are especially encouraged.

Grant applications are sought for 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. The use of advanced methods such as neural networks or expert systems is appropriate. Techniques that are nondestructive to the beams being monitored are especially of interest.

Grant applications are also sought to develop beam diagnostic devices that have increased sensitivities through the use of superconducting components, such as filters based on high Tc superconducting technology or Superconducting Quantum Interference Devices. Measurements of direct current charged particle average beam currents in the range 0.1 to 100 μA with very high precision ($<10^{-4}$) are also needed.

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* See Section 7.1

PROGRAM AREA OVERVIEW - HIGH ENERGY PHYSICS

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

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

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

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

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

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

36. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY PHYSICS ACCELERATORS

The Department of Energy (DOE) High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in the following areas: (1) new concepts for acceleration, (2) novel device and instrumentation development, (3) inexpensive electron sources, and (4) computer software that will contribute to overall advances in accelerator technology applicable to the High Energy Physics program. Relevance to applications in high energy physics must be explicitly described. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 35. Grant applications which propose using resources of a third party (such as a DOE Laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. New Concepts for Acceleration—Grant applications are sought to develop new or improved acceleration concepts to provide very high gradient (>100 MeV/m for electrons and >20 MeV/m for protons) acceleration of intense bunches of particles. Stageability, beam stability, manufacturability, and high wall plug-to-beam power efficiency must be addressed in detail. Grant applications must also address the marketability of any systems, technologies, and devices to be developed.

b. Novel Device and Instrumentation Development—Grant applications are sought for the development of electromagnetic or permanent magnet 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 small electron linear accelerators, and solenoids for use in electron-beam or ion-beam sources or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.1 to 10 cm. Permanent magnets in these optical elements which are made

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with materials having 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 in small radius (0.1 micrometers to 5 millimeters diameter), short (10 micrometers to 10 millimeters length) 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 to the beams monitored and have computer-compatible readouts); and (3) compact multi-terawatt laser systems for laser-accelerator applications.

Regarding (3) above, the multi-terawatt laser systems must be capable of providing at least 1 J energy in 50 femtoseconds in ultra-short pulse, single frequency operation at a high (around 10 Hz or greater) repetition rate. Alternately, such a system must be capable of providing approximately 60 J energy in 4 picoseconds in dual frequency (for example, near 1.05 micrometer and 1.06 micrometer) operation with a repetition rate of better than 2 per hour. Applications that promote novel systems architecture (e.g., multi-pass or bow-tie amplifiers to obtain compactness) and the ability to manipulate pulse shapes using phase masks are highly desirable. The laser pulses must be able to be synchronized with an electron beam generated by a radio frequency linac to a high level of precision (less than approximately 1 picosecond cycle-to-cycle jitter).

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 the development of radio frequency photocathodes (robust, with quantum efficiencies >0.1 percent) or other novel rf gun technologies operating at output electron beam energies >3 MeV. Laser or electron driven systems for such guns are also sought. Cathodes are needed for vacuum-electronic devices such as klystrons, gyrotrons, and high brightness electron sources for accelerators. Currently, they have many limitations: conventional thermionic cathodes are limited to about 10 amps/cm^2; reservoir cathodes can operate at higher temperatures and can deliver up to 40 amps/cm^2, but may have life limited by the build-up of deposits from the evaporated barium oxide; photocathodes require expensive lasers, and plasma cathodes have limited life. Grant applications are solicited for research and development leading to rugged, long-life cathodes or electron guns that are capable of producing current densities and currents (several hundred amperes pulsed) comparable or greater than thermionic emission devices. Applications must focus on one of the following areas of interest: (1) use of secondary emission to amplify a lower current density beam to generate a higher density one, (2) arrays of field emission needles and knife edges (these have been studied extensively but are still easy to damage and hard to use), (3) use of field emission from diamond films or other surfaces at higher pulsed fields (flat diamond films have been found to yield significant current densities with relatively low fields), (4) use of ferroelectric cathodes, and (5) new methods for bonding evaporated barium oxide in reservoir cathodes – because evaporated material sometimes peels off and causes breakdown, improved bonding could increase the lifetime of devices using such cathodes.

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

d. **Computer software**—Grant applications are solicited for developing new or improved computer software specifically for the design or study of charged particle beam optical systems, accelerator systems, or accelerator components. Such applications should incorporate the innovative development of user-friendly interfaces with emphasis on graphical user interfaces and windows. Grant applications are also solicited for the conversion of existing

codes to incorporate such interfaces, provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate.

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

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

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

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

Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 35. Grant applications which propose using resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. 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 >20 MeV/m for protons in normal cavities are of particular interest, as are means for suppressing unwanted higher-order modes and reducing costs. Means for achieving unloaded voltage gradients >20 MeV/m and reducing costs in superconducting cavities are also of interest, as are methods for reducing surface breakdown and multipactoring (such as surface coatings or special geometries) and for suppressing unwanted higher order modes. Grant applications should be applicable to devices operating at wavelengths from 1.2 to 100 GHz.

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

For example, 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. Grant applications are sought to develop cluster klystrons, as well as highly stable magnetron guns for cluster klystrons.

Upgrades to the next generation linear collider will require many radio frequency power handling components which are not presently available, e.g., rf windows, couplers, mode transformers, rf loads, and high power rings capable of operating at high pulse powers (20 - 100 MW), high frequencies (11 - 100 GHz), and pulse lengths of several microseconds. Areas of interest include passive

and active rf components such as over-moded mode converters from rectangular to circular waveguide, high-power rf windows, circulators, isolaters, switches, and high-power rf pulse compression methods for use in future linear colliders.

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

c. New Concepts for Pulsed Power Modulator—Most rf power sources for future linear colliders require high peak-power pulse modulators of considerably higher efficiency than presently available. Grant applications are sought for new types of modulators in the 400 kV - MV range for driving currents of 400 - 800 A, with pulse lengths of 0.2 - 2 microseconds, and rise- and fall-times of less than 0.2 microsecond. Innovation related to cost saving, manufacturability, and electrical efficiency in modulators is especially important. Modulators or their components with improved voltage control for rf phase stability in some alternate rf power systems are also sought.

A special case of interest is synchronized alternating current (AC) sources for powering gridded or modulator-controlled vacuum electronic devices. These devices can be operated with simple direct current (DC) or synchronized sources, but breakdown can be reduced with synchronized AC sources by using a nonlinear circuit to sharpen the voltage swings in the desired direction and flatten them in the opposite direction. One example is a transformer with a biased, saturating short. Grant applications are sought for new technical approaches to, and development of, synchronized ac sources for powering gridded or modulator-controlled vacuum electronic devices operating at high power, with a special focus on electrical efficiency and manufacturing economy.

Note: Grant applications for components and systems which target the presently envisioned Next Linear Collider should be submitted under Topic 39.

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

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

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

a. High-Field Superconductor Technology—Grant applications are sought for new or improved materials and related processing techniques for high critical-current, high critical-field conductors to produce low alternating current (AC) loss conductors for use in very high-field magnets. While improvements are sought for magnets above 8 Tesla, the engineering goal for the near future (7 to 10 years) is at least 15 Tesla. Applications must demonstrate such property improvements as higher critical-current densities and higher critical fields, as well as manageable degradation of these properties as a function of applied strain. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K. Process improvements must result in equivalent performance at reduced cost. Advanced conductor fabrication techniques of interest also include methods to utilize high aspect ratio stranded conductors or tape geometries in particle accelerator applications. Materials of interest include: niobium-titanium, ternary niobium-titanium alloys, the so-called "A-15" compounds (e.g., niobium-tin and niobium-aluminum), and oxide (high temperature) superconductors. Regarding oxide superconductors, a minimum current density of 1200 A/mm^2

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(not cm^2) in the superconductor itself and a minimum current density of 250 A/mm^2 over a total conductor cross section, at 12 Tesla minimum and 4.2 K, must be achieved. All grant applications for A-15 and oxide superconductors must address the challenge of long length, large volume industrial production for practical applications. The details of such production plans, including expected development time, also must be discussed.

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

b. Superconducting Magnet Technology—Grant applications are sought to develop: (1) improved instrumentation to measure properties (such as local strain, temperature, and magnetic field) which are directly applicable to the testing of superconducting magnets; (2) improved current leads based on high-temperature superconductors for application to high-field accelerator magnets, which have requirements that include current level at 5 kA or greater, stability, low heat leak, and good quench performance; (3) alternative designs, to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets, that may be more compatible with the more fragile A-15 and the oxide, high-field superconductors; or (4) designs for bent (e.g., bending radius of 0.5 meter) solenoids (e.g., 4 T, 30 cm inside diameter) with superimposed dipole fields (e.g., 1 T) for dispersion generation in large emittance beams.

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39. 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 ten times the size of present-generation linear accelerators. This topic addresses near-to-medium term developments to enhance performance and reliability and/or to reduce costs of accelerator components and infrastructures. Applications should demonstrate relevance to these issues. Any letters included in an application which indicate the use of resources of a third party (such as a DOE Laboratory) must include certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

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a. Direct Current (DC) and Pulsed Power Supplies, Modulators and Components—Grant applications are sought to develop power supply controllers for highly reliable power systems planned to energize DC magnets individually or in series in beam lines. The power supply configuration to be controlled must include sufficient redundancy (e.g., parallel architecture) to assure uninterrupted operation if a supply fails, as well as the ability to replace a failed supply with minimum interruption. Typical magnet loads to be controlled are in the range of 1-50 kW. It is desirable that the systems have a MTBF greater than 100,000 hours and an efficiency greater than 90 percent.

Grant applications are also sought for the development of pulse modulators for klystron amplifiers. Each modulator must deliver a 500 kV pulse into an impedance of 1000 ohms at repetition rates up to 120 Hz. The rise and fall times of the voltage pulse must be <300 ns and the output flat-top must be 1.5 - 1.8 microsec. Modulators may be designed to drive a single klystron load of 260 A peak, or up to eight klystrons at 100 pF each in parallel. The modulators must also provide high efficiency, reliability, and maintainability, and be producible at low cost.

Lastly, grant applications are sought for the development of the following modulator components with the noted specifications:

(1) Power Supply for Dual Klystron Modulator providing 100 kW to charge a pulse forming network (PFN) of total capacity 0.2 microF to a maximum of 80 kV in less than 5 millisecond with electrical efficiency greater than 90 percent, or a DC capacitor bank from which an on-off switch can deliver energy. The supply must be compact in size, highly reliable (MTBF > 50,000 hours), and cost-effective to manufacture and maintain.

(2) 5 kV DC Supply configurable from 30 kW up to 250 kW to drive capacitor banks in IGBT switched induction modulators or Marx generator type configuration. It must have high reliability, low cost and >90 percent efficiency.

(3) High-Power "On" and "On-Off" Switches capable of operating at 80 kV and switching from about 300 to up to 4,000 amps in 100 ns for 1.5 - 6 microseconds at 120 Hz. The switch should have MTBF > 50,000 hours and the total operating power should be minimized.

(4) Ultra-Reliable Capacitors of ~10-25 microfarads at 5 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, lifetime of >100,000 hours, and low cost. Lifetime is a priority concern since the capacitors, due to their large numbers, will dominate overall modulator reliability.

(5) Pulse Transformers: Either or both of two specific transformers are sought. The first transformer (ratio 1:7) must convert 72 kV from a direct switch to 500 kV, 530 A for a klystron load. Pulse width is 1.5 microsecond flat top with rise time less than 300-400 ns and droop and ripple less than 2 percent. The second transformer (ratio 1:14) must convert 35 kV/7,500 amp PFN pulses to 500 kV/530 amp pulses (with 1.5 microsec flat-top with rise time < 300 ns and droop and ripple < 2 percent) that will drive two 0.75 microperv klystrons in parallel, with capacitance of 100 pF each. The transformer must operate in 30 kV breakdown transformer oil, be compact, efficient, and cost-effective to manufacture.

b. Microwave Power Technologies—The X-band klystron developed at SLAC for the Next Linear Collider (NLC) main linacs (Model XP1) is focussed by 60 half-rings of periodic permanent magnets (PPMs). The NLC's injector accelerators could be energized by the same S-band klystrons (Model 5045) that power the SLAC two-mile linac, and by a similar klystron at L band. The 5045 beam is focussed by an electromagnetic solenoid. Grant applications are sought for new designs for X-, S-, and L-band klystrons and/or PPM structures of reduced cost or improved reliability.

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

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processes with similar tolerances and applicability for the mass production of UHV, high-power parts made from stainless steel, aluminum, or copper alloys are also of interest.

c. Auxiliary Systems—Grant applications are sought to develop either of the following: (1) a commercial capacitance-based inertial vibration sensor to measure inertial motion of objects with sub-nanometer accuracy in the range of 0.1 - 100 Hz, or (2) a translational mover system with sub-nanometer resolution for moving an electromagnet in an accelerator beam line. The mover should have the capability to move a 1000 kg load at speeds up to 5 nanometers/millisec with a dynamic range of 100 microns. The mechanical resonant frequency for the system should exceed 200 Hz.

d. Controls & Instrumentation—Innovative software and hardware architectures are needed for application in a large scale distributed controls system; e.g., computer systems that integrate support for data acquisition from distributed front-end electronics with high quality of service data transmission among peer computer systems. The control system should support parallel connection of communication links that provide error correcting transmission and small latency for both high priority synchronous links and normal priority asynchronous links. Grant applications are sought to develop one of the following:

(1) Accelerator Control System Graphical User Interface (GUI): A next generation, web-based interface will be needed for a distributed large-scale control system. The interface should allow the use of a variety of display hardware formats including operator consoles using workstations, desktop personal computers (PCs), hand-held Personal Digital Assistants (PDAs) as well as other web-aware display media. The interface needs to provide a rich set of active engineering measurement and control widgets, graphics, video, and voice and data visualization tools in addition to providing programming interface definitions for general application programs. Note that control systems have visibility and update requirements that are not accommodated by standard browsers. Some of these requirements are: no scrolling; all data must always be visible; all widgets must resize when the window is resized; frequent updates to small areas of the screen; and use of specialized page-building tools.

(2) Enterprise-Wide Database: Tools and methodology are needed for modeling a myriad of devices and objects involved in the control and operation of a large-scale accelerator. The tools must decrease the development and personnel resource requirements for the design of real-time data tables, entry of data items, or the generation of real-time data tables from enterprise databases. Programming interfaces and protocols are also needed to allow use of such databases as the centerpiece of a large set of distributed real-time applications software. Connectivity to numerous data sources in individual desktop PCs and workstations must also be provided.

(3) Large-Scale Client-Server Applications Software Development: Tools and methodology are needed for use by a software team in the design and implementation of large-scale application programs. Such applications will be based on a client-server paradigm and will interface to a large distributed system via an Application Program Interface (API). The API is one of the tools that are needed. The methodology should incorporate the concept of distributed objects, where the distribution occurs over a large functional space, a significant geographical area, and a large network address space (numerous network nodes). Note that the architecture must support high data rate collection of massive amounts of data, with low latency for a significant subset of the data.

(4) Software Device Drivers: Tools are needed that can manufacture software device drivers for communication with data acquisition and control modules. These device drivers must interface to commonly used, high-level accelerator software systems such as EPICS.

(5) Beam Position Monitor Electronics: Beam Position Monitor (BPM) electronics generate an estimate of beam position by digitizing the amplitudes of signals induced by the beam on pickup elements in the beam pipe. The accelerator operates at 120 Hz, at which rate bursts of 120 bunches of 10^{10} electrons per bunch, separated by 1.4 ns, are accelerated down the beam pipe. The BPM system must measure the position of each burst to an accuracy of one micron in a beam duct of radius 6 mm. Existing BPM digitizers have the precision and bandwidth required, but do not provide adequate sampling rate to meet the NLC requirement for multiple beam position measurements in a single 200 ns beam burst. Solution of this sampling rate issue, as well as requirements on reliability, ease-of-

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manufacture, and economy, suggest that the channel processing electronics be integrated on a chip. Grant applications must address radiation tolerance, as exposure of the electronics to 1 Mrad over 10 years is possible.

(6) Instrumentation Tunnel DC Power and Communication: Novel DC power bus distribution is needed in accelerator tunnels, e.g. 48 V, that combines low bandwidth control and monitoring with power distribution through a single connector to an on-line device such as a modular vacuum pump controller. Exposure to radiation of up to 1 MR integrated dose must be addressed.

(7) Vacuum pump controllers: Controller chips for modular, low-power vacuum (ion) pump power supplies with integrated readout are needed that have the capability of conversion to a radiation tolerant, integrated design with an integrated power supply communication system.

(8) Systems for Personnel Safety and Monitoring: Personnel safety systems in accelerators are function-critical and require: (1) redundancy and fail-safe implementation of all features, (2) serial fiber or copper links from single entry points, (3) firmware reconfigurability, (4) modular architecture, (5) high reliability, (6) radiation tolerance, (7) optical or inductance interrupt switches, (8) high-security card-reader key technology, and (9) combined data, audio, and video to remote monitoring and control. The following components are of interest: non-contact radiation tolerant door position sensors; radiation tolerant secure redundant serial data links & protocols; integrated entry modules with built-in self test features; secure fail-safe software for redundant programmable controller systems; and alternative system architectures to minimize programmable controllers with distributed redundant firmware solutions.

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* See Section 7.1.

40. HIGH ENERGY PHYSICS DETECTORS

The Department of Energy (DOE) supports research and development in a wide range of technologies essential to experiments in high energy physics and to the accelerators at DOE high energy accelerator laboratories. The development

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

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

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

b. Novel Experimental Instrumentation Systems—Grant applications are sought for novel experimental instrumentation systems which use new detectors or use old ones in new ways that either extend basic high energy physics experimental research capabilities or result in less costly and less complex apparatus (e.g., improved or less costly calorimeters or vertex detectors). The proposed instrumentation system must be explicitly related to future high energy physics experiments, either accelerator or non-accelerator based, or to future uses in particle accelerators.

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41. HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

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

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

a. High-Speed Electronic Instrumentation—This subtopic includes: Components - Grant applications are sought for special purpose chips and devices for use in the internal circuitry employed in large particle detectors. Desirable features include low noise, low power consumption, high packing density, radiation resistance, very high response speed, and/or high adaptability to situations requiring multiple parallel channels. Desirable functions include amplifiers, counters, analog pulse storage devices, decoders, encoders, analog-to-digital converters, controllers, and communications interface devices.

Electronics - Grant applications are sought for circuits and systems 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.

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

Instrumentation Modules - 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). Grant applications are sought for modules that will provide capabilities not previously available, for substantial performance

enhancement to existing types of modules, and for components, devices, or systems that will enhance or significantly extend the capability or functionality of one of the standard systems. Examples include large and/or fast buffer memories, single module computer systems (either general purpose or special purpose), display modules, interconnection systems, communication modules and systems, and disk-drive interface modules.

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

c. **Distributed Collaborative Infrastructure and Distributed Data Management and Analysis Frameworks**—Advanced computational tools and software are needed to strengthen the ability of dispersed particle physics researchers to collaborate and to address problems related to the handling, analysis, and visualization of large datasets by these distributed collaborations. Grant applications are sought to develop: (1) interactive collaborative tools appropriate for diverse computers and wide area networks; (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) interconnects and other peripherals which allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual; and/or (8) software development tools for the production of computer software to meet identified problems related to distributed, large scale software development, configuration management, and data analysis. For (8), approaches of interest include distributed portable testing and Computer Aided Software Engineering (CASE), including configuration management tools for a portable, distributed environment.

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PROGRAM AREA OVERVIEW - OFFICE OF FUSION ENERGY SCIENCES

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

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

42. FUSION PLASMA SCIENCE RESEARCH

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

a. Diagnostics for Magnetic Fusion Plasma Research—Grant applications are sought to develop measurement techniques for parameters such as plasma density, electron and ion temperature, plasma current and current density, plasma position and shape, impurity density, magnetic field strength, ambipolar potentials, and radiation from the plasma. Diagnostics suitable for experimental devices using relatively low magnetic fields or burning plasmas are of particular interest. In addition, methods are desired for examining the edge and divertor regions in tokamak plasmas. Both new techniques and methods to improve the accuracy and resolution of existing diagnostics (e.g., improving the signal-to-noise ratio or extending the range of measured parameters) will be considered. Measurements must be both spatially and temporally resolved for both the absolute values of parameters and for small relative differences. For some of these parameters, real-time measurements will be an advantage in order to provide for plasma control. For additional information, see the summary of the February 1998 workshop addressing measurements needs in magnetic fusion devices, listed as one of the references.

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

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

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

Lastly, a code-development and run-time environment needed to facilitate advanced code steering for convenient user-programmable, interactive control in accelerator calculations. Grant applications are sought to develop one

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

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

Grant applications are also sought to develop software tools useful for the analysis and distribution of fusion data. Areas of interest include methods for coupling codes across architectures and through the Internet; techniques for making highly configurable scientific codes; data management and analysis techniques for large data sets; and remote collaboration tools that enhance the ability of a geographically distributed group of scientists to interact in real-time. The computer algorithms and programming tools should be developed using modern software techniques and should be based on the best available models of plasma behavior.

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43. ENABLING TECHNOLOGIES FOR FUSION PLASMA EXPERIMENTS

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

a. Superconducting Magnets and Materials—New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems; i.e., high field magnets (12 to 20 T) and low loss pulsed magnets. Grant applications are sought for: (1) innovative and advanced materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs; (2) cryogenic superconductor materials with high critical current density, low sensitivity to strain degradation effects, and radiation resistance; (3) novel, low-cost cable designs and fabrication techniques which minimize conductor strain; (4) superconducting joints for high field and pulsed applications; (5) novel, advanced sensors and instrumentation for non-invasively monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); (6) thick (15-30 cm) weldable structural case materials with high strength and toughness at 4 K; (7) welding techniques for such thick cryogenic structural materials; and (8) radiation-resistant electrical insulators (e.g., wrapable inorganic insulators and low viscosity organic insulators which exhibit low outgassing under irradiation).

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

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c. **Particle Control and Heat Removal**—Fusion plasma experiments, either operating or planned, require support technologies for the injection of plasma fuel at the required radial profile and the removal of undesirable helium ash and other impurities from the vacuum vessel. The components needed to accomplish these goals, as well as related support functions, require plasma facing materials which must perform under harsh environmental conditions including high heat and particle flux, high temperatures, and plasma-induced erosion, as well as neutron irradiation from burning plasmas.

With respect to plasma fueling, some modest advances have been accomplished. Hydrogenic pellet injectors have demonstrated required fueling rates for short pulse lengths, the initial development of some tritium injection components (e.g., ice extruders) has been completed, and, in preliminary experiments, pellets launched from the region near the tokamak axis achieved moderate injection speeds and acceptable density profile control. Grant applications are sought for advanced techniques for fueling high temperature plasmas in magnetic fusion experiments in order to provide for longer pulse lengths, higher pellet speeds, more flexible launch locations (e.g., high/low magnetic field side, vertical injection), and greater reliability. Improvements to the widely used deuterium or tritium pellet injectors are sought, as well as alternative fueling concepts. In a related technology area, grant applications are also sought to mitigate plasma disruptions by rapidly injecting massive amounts of hydrogenic fuel (gas, liquid or solid).

With respect to pumping helium ash or other impurities from the vacuum vessel and other fusion plant components, existing configurations use turbomolecular or cryogenic pumps to control the base pressure of the vessel. However, in large fusion power systems with high throughputs (e.g., ITER), the cryopumps require periodic regeneration. Grant applications are sought to develop innovative vacuum pumping systems that can pump hydrogenic ions and plasma impurities at high throughputs and efficiencies, while maintaining modest tritium and hydrogenic inventories for recycling. The corresponding development of associated vacuum system components (such as reliable long-life vacuum valves, reliable vacuum sensors, and remote equipment for localizing small vacuum leaks) is also desired.

With respect to plasma facing materials, grant applications are sought for: (1) radiation resistant and high thermal conductivity materials and concepts to remove high surface heat flux and to control erosion and deposition for limiters, divertors, wall armor, and liners; (2) heat dissipating materials and concepts; (3) techniques to enhance heat transfer and critical heat flux limits; (4) *in situ* inspection and repair techniques for damaged armor; (5) methods for cleaning plasma facing surfaces with emphasis on the *in situ* removal of co-deposited tritium layers; and (6) non-destructive evaluation techniques for armor joints and critical heat flux monitoring. All materials and components proposed must be able to withstand surface heating conditions, which include long pulse (tens of seconds to steady state) heat fluxes for first wall components (0.1 to 2 MW/m^2) and for limiter and divertor components (5 to 50 MW/m^2). In addition, materials and components which are also capable of accommodating short pulse (about one thousandth of a second) heat fluxes on surfaces subjected to plasma disruptions (10 to 500 MW/m^2) are of particular interest. Grant applications must clearly identify proposed materials and configurations and include preliminary analysis to indicate the potential for achieving the performance capabilities sought, including maximum and minimum temperatures of key materials. Grant applications pertaining to the use of liquid surfaces or the use of silicon carbide composites will not be considered; these should be submitted under the topic, Advanced Technologies and Materials for Future Fusion Energy Systems.

d. **Technology for Heavy Ion Fusion Accelerators**—A number of different technologies are needed for the development of heavy ion accelerators as a viable fusion concept. Grant applications are sought for: (1) pulsed power systems to drive linear induction accelerator modules capable of providing kiloampere ion beams (1-10 kA at 10 kV to 2 MV) and repetition rates from a few Hz to 200 kHz, including the use of multiple beams merged to form a single unit; (2) automated, low-cost mass production of medium field (3-6 T) superconducting quadrupole arrays for transport of high momentum multiple parallel beams of heavy ions, with aperture radius of 2 to 10 cm and lengths of 20 to 100 cm (exact dimensions of the beams are determined by the particle mass, energy, current, and operating field, all of which are subject to systems optimization in various sections of the accelerator); (3) low-cost insulating materials for high voltage accelerating columns greater than 20 inches inside diameter, which are capable of having electrodes embedded during the manufacturing process, and which also have low outgassing, to maintain vacuums less than 10^{-8} Torr; (4)

magnetic induction cores that are annealed after winding, operate over magnetization rates of 0.1 to 20 T/μs, have a lifetime of ten billion shots, and have a remnant magnetic field greater than 60 percent of the saturation field (in addition, the interlaminar insulating coatings for the magnetic induction cores must withstand a minimum of 10-100 V, depending on the magnetization rate); and (5) automated low-cost mass production of such magnetic induction cores with 1-2 m inside diameter, and a mass near 1 ton.

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44. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUTURE FUSION ENERGY SYSTEMS

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

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

b. Free Surface Liquids for Heat Removal—Innovative invessel component concepts are desired for heat removal from high power densities (surface heat fluxes at first wall and divertor 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 a flowing liquid with direct exposure to the plasma. Candidate liquids include lithium, tin-lithium, gallium, lithium-beryllium fluoride salts, and lead-lithium. Grant applications are sought to develop: (1) techniques for the removal of significant heat loads (at least 2 MW/m^2) by free surface flowing liquids (proposed techniques should address the effect of magnetohydrodynamics on heat transfer and should also consider heat removal enhancement techniques such as turbulence promoters), (2) efficient nonlinear solution methods, as well as alternate object-oriented languages for computational tools, to model fusion-relevant issues of liquid wall flows (such as heat transfer at free surfaces and free flows with magnetohydrodynamic effects and turbulence), (3) techniques, such as the addition of alloying materials, to suppress surface vaporization, (4) nozzles for liquid injection (streams, films, and droplets) and collection/removal that are drip and splash free, self-cooling,

and efficient in head recovery at the outlet, and (5) non-invasive diagnostics for experiments to study both transparent and opaque high temperature free surface liquid flows in magnetic fields (such diagnostics might include measurements of mean flow velocity, turbulence intensity, velocity fluctuations, flow depth, and surface/depth temperature profiles).

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PROGRAM AREA OVERVIEW - NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

http://www.ne.doe.gov

Continued use of nuclear power is an important part of the Department's strategy to provide for the Nation's energy security, as well as to be responsible stewards of the environment. Nuclear energy 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. make a significant contribution to lowering the emission of gases associated with global climate change.

The Office of Nuclear Energy, Science and Technology (NE) enables the Department of Energy to provide the technical leadership necessary to address critical domestic and international nuclear issues by administering research and development and technical assistance in the following general areas: (1) the Nuclear Energy Research Initiative Program addresses key issues affecting the future of nuclear energy in order to preserve U.S. nuclear science and technology leadership; (2) the Radioisotope Power Systems Program develops new, state-of-the-art radioisotope power systems to support the NASA space missions and terrestrial applications for other government agencies; (3) the Nuclear Energy Plant Optimization Program conducts research to assure the continued safe and reliable operation of over 100 of the Nation's nuclear power plants; (4) the Electro-metallurgical Treatment Technology Program addresses the disposition of the spent nuclear fuel remaining from the shutdown of the Experimental Breeder Reactor in Idaho; (5) the University Reactor Fuel and Educational Assistance Program is designed to help retain U.S. nuclear engineering capability for conducting nuclear research, addressing pressing nuclear environment challenges, and preserving the nuclear energy option; (6) the Depleted Uranium Hexafluoride Program addresses the long-term management strategy for depleted uranium hexafluoride material, including the identification of markets and uses for depleted uranium products; and (7) the Isotope

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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.

45. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power is an important component of the Nation's energy supply system, providing about 22 percent of the U.S. electricity without emitting harmful air pollutants, including those that cause adverse global climate change. New concepts are needed to address key issues affecting the future of nuclear energy and to preserve U.S. nuclear science and technology leadership. This topic addresses several of these key issues: new concepts for small nuclear reactors; simulation and modeling techniques for design, development, and evaluation of both new and on-going reactor concepts; and improved thermoelectric materials and joining techniques for radioisotope power systems, needed to support the U.S. space program. **Grant applications are sought only in the following subtopics:**

a. Small Nuclear Energy Reactor Concepts—Grant applications are sought for the design and demonstration of key components of small scale nuclear reactors for use in developing countries and for specialized applications. Ultimately, the desired nuclear reactor would have the following features: (1) low-power, high efficiency, capability from 50 to 300 Megawatts; (2) fuel cores with long operating lives; (3) proliferation-resistance for both the reactor and associated fuel technologies; (4) passive, built-in, safety and environmental systems; (5) easily transportable and deployable at the site; and (6) scalable, compact, reliable, and safe. Grant applications should focus on new concepts that would address one or more these features.

b. Simulation and Computer Modeling Applications—Advanced computer simulation techniques are needed for the design, development, testing, and evaluation of advanced nuclear power reactor systems. Grant applications are sought for new software simulation and modeling applications for one or more of the following: (1) design, development, and experimentation support of a full range of new and existing nuclear reactors and major reactor components, including advanced fission fuel core thermal-hydraulic design features; (2) remote, automatic characterizations of nuclear waste and by-product materials from nuclear power plants; (3) assessment, measurement, and control of nuclear reactor plant performance, integrity, and operations; (4) critical measurement of nuclear system operation/performance and telecommunication to a host of network interconnections (with automatic warnings, to both operating personal and the surrounding population, of any harmful environmental and safety conditions, including prior notice when performance thresholds are exceeded).

Proposed modeling approaches must: (1) be flexible for a range of reactor designs and concepts; (2) address issues of scalability, verifiability, and validation; (3) be suitable for use with state-of-the-art high-speed parallel processing computer equipment; and (4) describe the computer parameters (e.g., speed, size, access time) needed for the research and development phase. Subject to program office approval, the Department of Energy expects run time to be made available on government high-speed parallel computing equipment for grant applications selected for award.

c. Thermoelectric Materials for Radioisotope Power Systems—Radioisotope power systems continue to be the main source of power for deep space vehicles in the U.S. space program. In these systems, thermoelectric materials are used to convert the thermal energy from the decay of the radioisotope fuel to direct current electrical energy. However, improvements are required in the performance of the currently-used thermoelectric materials (baseline bismuth telluirede and silicon germanium types). Performance parameters of interest include thermal stability, mechanical strength, and the figure of merit, $Z = S^2/\rho\kappa$, integrated over the operational temperature range, where S is the Seebeck coefficient, ρ the electrical resistivity, and κ the thermal conductivity. Grant applications are sought to develop improved thermoelectric materials and associated devices for both low temperature (25 to 250°C) and high temperature (300 to 1000°C) applications (see references 1, 2). Improvements in the above performance parameters must be at least 25 percent greater than currently possible for state-of-the-art materials.

d. Joining/Brazing Technology for Radioisotope Power Systems—Grant applications are sought to develop an improved manufacturing process for joining the "beta" Alumina Solid Electrolyte (BASE) tube (nominal 0.35 inch diameter by 0.025 inch wall) to a columbium-1% zirconium

structure (see references 3, 4). Various joining methods will be considered, including brazing or the use of ceramics. The following conditions must be met: (1) the joint material must be compatible with sodium vapor at 900°C for at least a twelve-year service period; (2) the joining/brazing method and material must also be compatible with the BASE electrical transport properties; and (3) the joined/brazed assembly must have a helium leak rate from $1x10^{-9}$ to $1x10^{-4}$ Standard Cubic Centimeters(SCC)/minute over a twelve year service period, with up to ten thermal cycles from 900°C to ambient within the first year.

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* See Section 7.1

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