DOE/ER-0706

CYCLE 16

SMALL BUSINESS INNOVATION RESEARCH

PROGRAM SOLICITATION

Closing Date: March 2, 1998

U.S. Department of Energy
Office of Energy Research
19901 Germantown Road
Germantown, M.D. 20874-1290

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Department of Energy Solicitations for upcoming years are expected to be released at approximately the same dates (early October for STTR and early December for SBIR). Please make a reminder note on your calendar. To receive electronic notifications from the Department, you must notify the SBIR/STTR office of your e:mail address.

MAJOR DIFFERENCES BETWEEN DOE SBIR PROGRAM SOLICITATIONS IN FISCAL YEARS 1997 AND 1998

- The 200% indirect cost requirement has been eliminated. (See Section 3.3.5.b.) Instead, to assure that the level of research effort is consistent with DOE's investment in the project, the evaluation criterion, "Ability to Carry out the Project" has been enhanced to include the cost effectiveness of the proposed work. (See Sections 4.2 and 4.3)

- An example of a completed budget form has been included. (See sample following Appendix C.)

- A Level of Effort worksheet has been included as page 2 of the Checklist (Appendix D) to assure compliance with the requirement that the small business must perform at least two-thirds of the research or analytical effort (section 3.3.5.a). This completed form should be submitted with the application as part of Appendix D and will be exempted from the 25 page limitation as discussed in Section 3.2. (See Appendix D.)

- The competitive areas for SBIR grant applications have been clarified. Grant applications are effectively in competition with others submitted to those technical topics that belong to a single DOE program area. (See Section 4.2.)

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SBIR

Small
Business
Innovation
Research

Technical

Topic

Descriptions

TECHNICAL TOPIC DESCRIPTIONS

The technical topic descriptions for this solicitation are given below. The topics are arranged by DOE program area 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 - FOSSIL ENERGY

http://www.fe.doe.gov

Our nation's economic prosperity is built on national energy supply and security. Fossil energy plays a key role with contributions mainly from coal, 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. Unfortunately, the emission of global warming gases and pollutants would increase as well, and the present use of our fossil energy resources would not be environmentally sustainable. Therefore, an important mission of the Office of Fossil Energy is to develop advanced technology for the efficient and cleaner utilization of these energy resources.

Technological innovation is required to take advantage of the world's largest coal reserves that could last us for many generations. Although our reserves of oil and gas are limited, coal has the potential to be converted into oil and gas for specific applications. Moreover, recent developments have demonstrated that coal could be a major resource for almost all kinds of hydrocarbon fuels and raw materials. Its major drawback is that coal 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. Reductions in the amount of environmentally detrimental products will require the development of higher efficiencies for, and cleaner use of, coal and coal-derived fuels.

Our national petroleum reserve is limited by current extraction technology; about two-thirds cannot be extracted by conventional means. "Unrecoverable" petroleum represents an unused resource which could play a major role in supplementing the national petroleum supply. Technology must be developed to characterize these reserves and efficient approaches developed for improved extraction.

The reserves of natural gas, which can be used in a wide variety of applications requiring high efficiency and cleaner uses, are also limited. However, 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. These high efficiency

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applications demand high quality with a low tolerance for impurities. Low cost, efficient processes for the separation and purification of natural gas must be developed.

Finally, since combustion remains the most expedient means for converting chemical energy into mechanical energy for power generation and transportation, the generation of carbon dioxide has become an important environmental concern. Therefore, technology is needed to increase energy conversion efficiency and reduce carbon dioxide emissions in order to achieve an effective reduction in the production of greenhouse gases.

The following technical topics represent an attempt to utilize small business in the solution of significant aspects of these important problems.

1. ADVANCED OIL AND GAS TECHNOLOGIES

The Department of Energy seeks innovative methods and concepts that will contribute to more efficient and economic processes for the recovery of oil and natural gas. For oil, this topic focuses on improved techniques to characterize domestic oil resources and improved extraction technology to maximize domestic oil production. For natural gas, this topic focuses on reducing the risk of siting new wells by using reconnaissance tools to locate natural fracture systems in low permeability resources containing vast deposits of natural gas, and on reducing drilling costs by increasing the penetration rate of drill bits and by minimizing formation damage during drilling. **Grant applications are sought only in the following subtopics:**

a. Oil Reservoir Characterization—Grants applications are sought for innovative methods to characterize an oil reservoir in terms of its architecture (including geometric boundaries and how the boundaries change through time) and its fluid, rock, and fluid flow properties. Reservoir characterization methods of interest include: (1) high-resolution seismics, and (2) innovative software techniques for analysis (e.g., utilizing three-dimensional seismics and other logging data to determine heterogeneity and fluid flow in the reservoir). Only innovative ideas will be considered, and grant applications that propose minor improvements to the current state-of-the-art will be declined.

b. Oil Recovery Technology—Microbial improved oil recovery (MIOR) is a promising method for recovering the remaining oil that cannot be economically recovered using conventional technologies. Grant applications are sought for: (1) the selection and evaluation of new high temperature and salinity tolerant microbial strains for MIOR; (2) the application of microbes to complement other recovery methods (e.g., polymer producing microbes for profile modification to enhance waterflood efficiency, crude oil modifying microbes to assist in chemical flooding, etc.); and (3) the application of MIOR to heavy oil reservoirs. Grant applications concerning the application of microbes to the remediation of environmental or surface pollution will be declined.

c. Gas Reservoir Diagnostics—Grant applications are sought for innovative methods for detecting natural fracture systems in gas reservoirs with emphasis on their orientation, spacing, and areal extent. Methods of interest include three-dimensional seismic techniques (e.g., using longitudinal and/or shear waves), fracture system mapping from aerial reconnaissance, as well as innovative software for integration and analysis. A seismic technique of particular interest is the development of three-dimensional shear wave seismic technology and the computational analysis to indicate natural fracture spacing (on the order of 10, 20, and 30 ft). Successful detection of these fracture systems in prospective reservoirs could permit reliable assessments of expected production in advance of drilling.

d. Gas Reservoir Drilling—Innovative approaches are desired to reduce the cost of drilling natural gas wells. Grant applications are sought for products, technologies, systems and methods to: (1) increase the drill bit rate-of-penetration, and (2) to enhance the performance of underbalanced drilling technology in vertical, directional, and horizontal wells. In both cases, operation in a borehole environment, where a large pressure differential is maintained between the

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formation and the borehole, is a key condition for these technology challenges. If successful, production efficiency should increase from both the increased length of the well and from reduced formation damage (due to underbalanced drilling).

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U.S. Department of Energy, December 1993. (Report No. DOE-94007260) (NTIS Order No. DE94007260)*

* See Section 7.1.

2. ADVANCED COAL/GAS 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 new power plants based on advanced technology with the potential for high efficiency, low emissions, and reduced cost relative to today's coal-fired generating plants. For coal, these systems include advanced pulverized coal combustion technology, pressurized fluidized bed combustion (PFBC), and integrated gasification combined cycle (IGCC). For natural gas, the DOE is interested in innovative research that contributes to the efficient production of electricity in high-temperature fuel cell power plants, and in advanced heat engines with increased efficiency and specific power and reduced emissions and cost of electricity. New concepts are needed to further improve the performance and efficiency of these systems. **Grant applications are sought only in the following subtopics:**

a. Coal Combustion-Based Power Systems—About 85 percent of coal-fired power plants in the U.S. utilize the direct firing of pulverized coal. Future pulverized coal-based plants will need to be more efficient in order to compete with new gasification-based plants and to reduce emissions of carbon dioxide. The use of higher temperature and pressure (supercritical) steam would allow for increased thermal efficiencies; however, such an approach would be accompanied by conditions that would cause increased fouling and slagging of mineral matter and/or corrosion of metals. An alternative approach is to employ a thermodynamic power cycle that incorporates binary working fluids, e.g., ammonia-water. This may allow high efficiencies at lower temperatures and less aggressive conditions. Grant applications are sought to develop new concepts for binary fluid cycles that offer thermal efficiencies of at least 45 percent and plant capital cost reductions of at least 10 percent below the costs of conventional steam cycle plants.

As an alternative to pulverized coal combustion, PFBC is being investigated as a system for achieving high efficiency, based on a configuration which combines gas turbines with steam turbines. Although these systems have demonstrated reduced environmental emissions (e.g., flue gas desulfurization accomplished by mixing limestone or dolomite with the coal, NO_x emissions reduced through temperature and air staging, ceramic filters remove particulate matter from the hot combustor off-gas), innovations are required to improve the economics of the technology. In order to reduce operating and/or capital costs, grant applications are sought to develop novel concepts: (1) to improve the operating stability of fluidized bed combustion systems in the area of dense flow standpipes; (2) to facilitate the co-firing of opportunity fuels (high sulfur coal, petroleum coke, municipal waste sludges); or (3) for the utilization of FBC ash, other than for agricultural purposes, leading to commercially viable by-products.

b. Advanced Integrated Gasification Combined Cycle Technologies—The IGCC uses advanced technology to produce low-cost electricity. In this system, coal and other carbonaceous feedstocks are partially combusted at elevated temperatures and pressures to produce synthesis gas, a mixture of carbon monoxide and hydrogen, which must be cleaned of sulfur and particulates prior to combustion in a high efficiency gas turbine/generator. The hot turbine exhaust gas is used to produce steam to drive a steam turbine/generator for the production of additional electricity. Besides producing electricity, IGCC technology is ideally suited for the coproduction of high quality transportation fuels or a host of high-value chemicals to meet specific market needs. This coproduction option offers the potential for early introduction of IGCC technologies in the U.S. through integration with existing manufacturing facilities. DOE's goals for IGCC include further reductions in the capital cost of facilities, higher overall plant efficiencies, minimum carbon dioxide emissions, and the production of environmentally superior transportation fuels that are cost competitive with those produced from petroleum.

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Grant applications are sought to develop novel, oxygen-blown gasifier technologies that have potential for lower capital costs, improved utilization of oxygen, and higher thermal efficiencies, and which utilize a variety of carbonaceous feedstocks, either individually or in a co-fed mode.

Grant applications are also sought for novel, low-cost, reliable technologies for removing particulate and chemical contaminants from the raw, high pressure synthesis gas. Applications must show the potential for improved performance over (1) conventional cold gas cleanup technologies and (2) hot gas cleanup technologies, currently under investigation, that utilize barrier filters and sorbents. The clean synthesis gas must be suitable for both combustion in modern high efficiency gas turbines and for conversion to transportation fuels and/or chemicals.

c. High-Temperature Fuel Cells—High-temperature solid oxide (above 800°C) and molten carbonate fuel cell (SOFC and MCFC) technologies are important for stationary electric power generation. However, further performance improvements and cost reductions of the fuel cell package (i.e., cells for MCFCs and tubes for SOFCs) will be needed before these technologies become economically viable. Grant applications are sought to develop: (1) alternative materials or manufacturing methods that reduce the cost of separator or bipolar plates in MCFCs, (2) non-migrating and/or non-segregating carbonate electrolytes, and/or (3) methods for co-extrusion of interconnect and air electrode for SOFCs. Applications that focus on cost studies, or that propose approaches other than those described above, will be declined.

d. Advanced Gas Turbine Systems—Electricity generation from both natural gas and coal is projected to increase significantly in the U.S. through the year 2015 to meet increased demand and to offset the decline in electricity generation from nuclear power. With the low cost of natural gas, and the relatively low capital requirements for gas-fired capacity compared to coal-fired capacity, natural gas is expected to nearly triple its share of electricity generation. Consequently, the relatively low capital cost of gas turbines will enable gas turbines to capture a large portion of the growing electric power market; the Energy Information Agency estimates that gas turbines will satisfy up to 81 percent of new electric power demands. The achievement of ultra-high efficiencies for these gas turbine systems, along with a concurrent reduction in emissions, will require operation at higher temperature and pressures. Therefore, novel materials and components will be needed to withstand these conditions as well as the oxidation/corrosion environment of the working fluids, steam and product gases. Grant applications are sought for the development of the following materials used in advanced power systems for utility or distributed generation applications: high temperature thermal barrier coatings, bond coatings, and ceramic components.

Grant applications are also sought for lean pre-mix and catalytic combustion systems, including catalytic low NO_x combustion, and novel diagnostic techniques for monitoring turbine performance or for identifying operation or maintenance problems. Innovations should either contribute directly to the achievement of DOE Advanced Turbine System program goals or offer longer term performance enhancements.

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* See Section 7.1

3. TECHNOLOGIES FOR CLEAN FUELS AND SPECIALTY PRODUCTS

The conversion of coal, natural gas, and other carbonaceous material into more useful, cleaner fuels or into high-value products offers both economic and environmental advantages. For example, the development of technology to separate hydrogen from process streams could play a significant role in reducing the long-term environmental effects associated with burning fossil fuels. The production of new materials derived from coal could contribute to the greater utilization of our most abundant and inexpensive fossil fuel. The effective processing of carbonaceous material from municipal solid waste such as paper, rubber and plastics, as well as from waste oil, either by itself or in association with coal, could also be a potential source of clean fuels or specialty products. Lastly, much of the nation's natural gas resources could be enhanced through the development of technologies for converting natural gas to liquid fuels and for raising low-quality raw natural gas to pipeline quality.

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Technology is needed to address all of these issues. **Grant applications are sought only in the following subtopics:**

a. Hydrogen Separation System for Pure Hydrogen Production—The Clean Air Act of 1990 which calls for lower sulfur and aromatics content in gasoline and diesel fuels, and also calls for the increased use of alcohols/ethers as additives and fuels, essentially requires increased hydrogen-to-carbon ratios in transportation fuels. The demand for hydrogen must be satisfied by sources such as natural gas and other carbonaceous feedstocks. Regardless of the source and processes involved, there is a need to separate hydrogen from product gas streams. While methods for separating hydrogen are presently available, some are expensive and others do not produce the high-purity hydrogen required for some end-use applications.

Grant applications are sought for the development of novel processes for separating hydrogen from typical coal gasifier or methane partial oxidation/steam reforming product gas streams which are less capital and energy intensive than conventional commercial hydrogen separation processes. Hydrogen may be separated by proton-electron transfer membranes or by molecular sieves. Materials used for the hydrogen separating process must have sufficient mechanical integrity and be chemically stable under the high temperature (500-1000°C), high pressure (up to 4 MPa), corrosive environments typically encountered in gasifier or synthesis gas reactor exit conditions. Although H_2S separation is not a subject of this grant application, the development of sulfur-tolerant separation materials are encouraged.

b. Advanced Carbon Materials from Coal—Significant potential exists for meeting both current and future market demand for carbon-based materials used in strategic technologies such as gas separation and water and air purification. While materials such as carbon electrodes, carbon black, carbon fibers, whiskers, and filaments can be made from coal, coal tars, and coal-derived liquids, they have been manufactured predominately from petroleum feedstocks due to the latter's lower heteroatom content, which results in easier processing methodologies to achieve desired product quality. Grant applications are sought for novel, innovative concepts and processes to produce new or improved carbon materials, products, or precursors, from coal or coal-derived/coal-based sources (including coal/waste or coal/biomass mixtures) that can be economically competitive, or exhibit superior performance characteristics, compared to petroleum-based precursors. Of particular interest is the development of technology for the production of lightweight carbon products (e.g., high strength fibers), for use in the automotive or aerospace industries, which could contribute to vehicle weight reductions along with significant improvements in fuel efficiency and environmental quality.

c. Mobile Processes for the Conversion of Waste Materials—Technologies developed for or employed in the handling and processing of fossil materials have also been effectively applied in the conversion of certain types of waste materials to useful byproducts. However, the advantages of employing waste streams as feed materials are too often offset by the drawbacks associated with collecting, sorting, and transporting a given waste material to a central location for processing. Although the collective waste problem is enormous, it usually manifests itself as a series of niche problems that may be unique to either a particular waste type or a specific physical location. As one potential approach to ameliorating this problem, grant applications are sought for the development of mobile, or at least modular, processes for converting waste materials into either clean fuels or specialty products. Proposed processes must have the capability of being conveniently moved from one location to another so that the process can be made to go to the waste and not vice-versa. The proposed "plant" would of necessity be small and relatively simple.

There is no intent to limit grant applications based on the type of waste to be processed or the technology employed, except that the proposed process must be sufficiently mobile to make its application practical. Applications could include the processing of waste tires at tire dump sites, plastics at recycling or waste handling facilities, or the reclamation of waste oil at commercial and/or industrial sites where the oil is generated. In these examples, processing of tires could encompass technologies from shredding to pyrolysis and beyond; processing of plastics could encompass technologies from catalytic cracking to more efficient separation processes; and reclamation of waste oil could include technologies from filtration to distillation. The proposed idea must be environmentally sound and comply with existing environmental regulations, although this may not be entirely

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straightforward in the case of mobile facilities. Applications that involve direct combustion or incineration of the waste are not of interest and will be declined.

d. Natural Gas Downstream Processing and Utilization—Natural gas offers environmental benefits over other conventional energy sources and helps to offset increasing oil imports. However, some natural gas resources are remote from gas transportation systems or contain large amounts of nonmethane gases, which make them uneconomical to market as natural gas. The ability to convert these remote and potentially low-value gases to high-value liquids, or to remove nonmethane impurities in order to raise low-quality raw natural gas to pipeline quality, could have significant economic and energy efficiency benefits. Therefore, grant applications are sought to: (1) develop simplified processes for producing liquid fuels or liquid fuel precursors from unconverted feedstock, either through conversion processes or through new or improved separation techniques to remove desired products; and (2) develop small scale facilities, using membranes, absorption/adsorption techniques, and/or hybrid combination of these technologies, to remove unwanted impurities from natural gas (with respect to removing hydrogen sulfide, approaches must also address the subsequent or direct conversion to elemental sulfur or other environmentally benign products).

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* See Section 7.1

4. STRATEGIES FOR MITIGATION OF GREENHOUSE GASES AND POLLUTANTS

The relatively recent dependence on fossil fuels, especially coal, to produce electricity has led to increasing concentrations of atmospheric carbon dioxide and pollutants. Although significant advances have been made toward control of major pollutants from pulverized coal-fired power plants (e.g., scrubbers remove about 95 percent of sulfur dioxide and, where installed, selective catalytic reduction can remove 85 percent or more of nitrogen oxides), the human and environmental impacts of increasing CO_2 are uncertain. Other environmental issues relate to fine particulates (flyash particles and sulfate and nitrate aerosols, formed as a result of sulfur dioxide and nitrogen oxide emissions) and mercury.

To effectively address these concerns, the U.S. has developed the "Vision 21" concept in which fossil fuels are used to maintain energy security and economic prosperity in the 21st century while sustaining an enhanced global environment. Vision 21 combines advanced fossil-based power technology with environmental and fuel technologies to allow closure of the carbon cycle. This permits the opportunity for long-term, clean, and efficient use of our natural fuel resources to meet ever growing energy demands. **Grant applications are sought only in the following subtopics:**

a. Emission of Particulate Matter—While state-of-the-art electrostatic precipitators remove total particulates with more than 99 percent efficiency, concerns have been raised regarding ambient concentrations of fine particulate matter ($PM_{2.5}$). Secondary aerosols formed from the emission of SO_2 and NO_x as well as the emission of primary particulate matter have been linked to suspected health and environmental (e.g., visibility impairment) effects. The sources of fine particulates are numerous and include both anthropogenic activities and natural occurrences. Grant applications are sought to develop $PM_{2.5}$ measurement and monitoring technologies to further understand the relationship between emissions from pulverized coal-fired power plants and the ambient levels of fine particulate matter.

b. Emission Controls for Mercury—Although concentrations of mercury are very low in flue gas, the total volume of mercury generated is significant for a full-scale power plant. Mercury can be insidious in the environment, accumulating in the biosphere and reaching significant concentrations in certain body organs in animals, notably fish, at the top of the food chain, ultimately posing a risk to human health. However, there is no tradition of mercury control in the power generation industry. The distribution of both elemental and oxidized mercury varies from one type of coal to another and from one power plant to another, and no known absorbent removes both forms effectively. Grant applications are sought for control technology to remove 90 percent of mercury from the flue gas of coal-fired utilities, and for devices to accurately measure and speciate mercury emissions. Of particular interest is the development of novel sorbents, or other techniques, to augment existing atmospheric pollutant control devices (APCDs) (e.g., electrostatic precipitators, fabric filters, and wet/dry flue gas desulfurization) to remove mercury. Proposed approaches must not adversely impact the fly ash, calcium-based waste, or any waste/by-products resulting from the combustion of

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coal and removal of other pollutants from the flue gas. Also, new techniques must not cost more than the cost of augmenting current APCDs.

c. CO_2 Disposal—Grant applications are sought to develop innovative, technically sound concepts for the economical and ecologically feasible disposal of CO_2 using such potential storage sites as oil and gas reservoirs, unmineable coal seams, the deep ocean, or deep confined aquifers. Questions relating to storage time, storage capacity and integrity, ecological impacts, costs, and storage location must be addressed with respect to major sources of carbon dioxide. Proposed approaches must be suited to the needs of large industrial and utility emitters of CO_2.

d. Utilization of CO_2—In order to intervene with the atmospheric build-up of CO_2, the Department of Energy is exploring several options for its utilization, including the development of: (1) new products which contain large amounts of CO_2, (2) processes which simulate the naturally occurring geological CO_2 cycle, and (3) biological systems which offer long-term sequestration of CO_2.

Through chemistry, new durable materials can be developed, which not only utilize CO_2, but also provide the capacity for long-term storage. Grant applications are sought to develop innovative, energy efficient processes that produce a marketable material with the capability for binding CO_2 for 100 years. Where appropriate, new large-scale markets should be identified so that these CO_2-derived durable materials would be economically competitive. Also of interest is the utilization of CO_2 to produce fuels, effectively recycling the CO_2. Grant applications proposing products which offer only short term storage, such as soft drinks, are not of interest.

Grant applications are also sought to develop long-term sequestration options which simulate the geological CO_2 cycle, such as CO_2 fixation in organic or inorganic materials. For example, a process is being investigated for the capture and storage of CO_2 in the form of a mineral carbonate using peridotite or serpentinized peridotite rock. Such solutions may require a better understanding of CO_2 synthesis chemistry and/or the development of catalysts to accelerate the sequestration reactions. To be economically feasible, processes should generate saleable by-products. Possible by-products include iron oxide, magnesium carbonate, silica, magnesia, and HCl, subject to such constraints as the size of a potential market, transportation to the user, production cost, and product purity.

Lastly, biological systems may provide an alternative approach for sequestering CO_2 for 50-100 years. Previous approaches have sought to accomplish this by using algae, haptophytes, genetically engineered organisms, ocean fertilization schemes, and biohydrogen production. However, real-world productivity has been limited by such factors as light saturation, species robustness, susceptibility to predators and diseases, land use issues, and water and nutritional requirements. These factors, along with costs, must be considered in evaluating such concepts. Grant applications are sought to increase the productivity of biological systems for capturing and sequestering carbon dioxide by examining the factors that limit photosynthetic productivity. The ability to create and commercialize useful high value biologically-based products, especially biomass for power generation, is of primary interest.

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PROGRAM AREA OVERVIEW - COMPUTATIONAL AND TECHNOLOGY RESEARCH

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

The Computational and Technology Research program supports research in computational technology, laboratory technology research, and advanced energy projects, 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 Energy Research 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.

The Advanced Energy Projects (AEP) subprogram funds research to establish the feasibility of novel, energy-related concepts that span the Department's mission. These concepts are usually derived from recent advances in basic research, but require additional research to establish feasibility. In funded AEP projects, it is often the case that new, or previously neglected, research results become linked, for the first time, to a practical energy payoff for the Nation.

5. POLLUTION PREVENTION BY COST-EFFECTIVE REPLACEMENT OF TOXIC CHEMICALS

Toxic chemicals represent both an immediate safety problem and a potential source of pollution in soil and groundwater. The Department of Energy (DOE) and others are currently incurring significant expense to remediate toxic chemical releases that occurred in the past. In order to stop future environmental pollution at the source, it is desirable to develop non-toxic, biodegradable, and cost-effective replacements for these toxic chemicals.

For example, chlorinated solvents are not only pollutants but also a source of ozone depletion and ground level smog formation. The replacement of chlorinated solvents with non-toxic biodegradable, biochemical solvents, such as terpenes and lactic acid esters, would be a permanent solution to the problem. Ethyl lactate is an excellent non-toxic solvent, with low volatility, but it is currently sold for about $1.75 to $2.10 per pound versus about $1 per pound for petroleum-based solvents. Recent manufacturing process technology to reduce the sales price to $1 per pound or less has been developed at the laboratory scale and may now allow the development of ethyl lactate as a chlorinated solvent replacement.

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Another example is the use of toxic biocides in the oil, gas, paper, and other industries to control biocorrosion, fouling, and souring (production of hydrogen sulfide). About 15 to 30 percent of the corrosion leading to failures in all industries may be due to microbiologically influenced corrosion associated with localized pitting corrosion. Biologically active biocides are generally applied in higher quantities than necessary for effective treatment because all the bacteria in the bulk solution have to be killed rather than just surface bacteria where the corrosion takes place. Recent research results suggest that these toxic biocides can be replaced with non-toxic chemical corrosion inhibitors if they can be delivered to metal surfaces under biofilms. Development of these more benign inhibitors and delivery methods would allow low concentrations of chemicals to persist over extended periods of time, and modify the biofilm characteristics so that corrosion does not occur.

Finally, toxic surfactants are used widely in the cleaning and recovery of oil from sludges, and in other applications. Alternative surfactants, such as biosurfactants, that are non-toxic and biodegradable would eliminate safety problems and prevent environmental pollution resulting from the use of toxic cleaning chemicals. Research leading to cost-effective methods to manufacture these biodegradable alternatives would allow their commercial development and formulation for oil sludge cleaning/recovery operations. **Grant applications are sought only in the following subtopics:**

a. Replacement of Chlorinated Solvents—The Department of Defense (DOD) has set a goal to reduce its total releases of toxic chemicals to the environment and off-site transfers by 50 percent by December 31, 1999. DOE and most energy intensive industries also need substitutes to halogenated solvents in common use, which are the source of major groundwater pollution at DOE and industry sites. Grant applications are sought to develop formulations of non-toxic, biodegradable solvents, such as ethyl lactate, which can replace methylene chloride or related solvents on a 1:1 basis for parts cleaning and which can be cost-competitive (i.e., sold at about $1 per pound or less). Technology integration and demonstration should take place in Phases II and III.

b. Replacement of Biocides with Corrosion Inhibitors—Microbiologically influenced corrosion (MIC) is a significant problem in water systems associated with the gas, oil, refining, electric power, nuclear, chemical, and water transportation industries. For example, in the natural gas industry, up to 30 percent of pipeline failures due to corrosion involve MIC. Current approaches for mitigating MIC in gas and oil production involve using biocides, which can be quite expensive because its effectiveness varies from one environment to another; accordingly, treatment dosages tend to be conservative and very high. Even with recent improvements, chemical costs are still high, and certain operating conditions (such as well production shut-ins) can result in uncontrolled MIC problems for extended periods. As many of these chemical treatments come under increasing regulatory scrutiny and represent potential liabilities to various industries, environmentally acceptable treatments are needed.

Recent work suggests that corrosion inhibitors can be delivered to metal surfaces even in the presence of biofilms and prevent corrosion failures attributable to MIC without requiring the total control of bacteria in the bulk fluids. When properly delivered, some corrosion inhibitors, such as the quaternary amines and other organic film-forming inhibitors, can prevent microorganisms from attaching themselves to metal surfaces (without the need to disinfect the bulk fluids), thereby preventing many of the mechanisms by which MIC occurs. In addition, these inhibitors can be capable of penetrating to surfaces under active biofilms when applied with suitable delivery agents.

Grant applications are sought to develop improved chemicals and/or chemical delivery systems which can replace toxic biocides and allow corrosion inhibitors to adsorb to carbon steel surfaces in the presence of active biofilms and effectively inhibit localized pitting corrosion over extended periods (weeks or months) without frequent additions. In Phases II and III, both laboratory and field data should be acquired to verify the effectiveness of the proposed approaches for mitigating localized pitting corrosion under biofilms. Mechanisms of inhibition should be evaluated to develop approaches for improving chemical design.

c. Replacement of Toxic Surfactants with Non-Toxic Biosurfactants—A major problem faced by DOE,

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DOD, the petroleum industry, and other industrial users of petroleum products is the handling, cleaning, and disposal of oil sludge. Current methods utilize toxic, non-biodegradable surfactants to remove sludge from the tank. It is then disposed of in storage tanks, oil sludge pits, or ponds. Costs of storage increase as sludge storage space diminishes and sludge is burned to reduce its volume and its hazardous content so that cleanup and storage costs are minimized.

One approach which could lead to improved safety and reduced toxicity, and allow hydrocarbons to be recycled, is the use of biodegradable non-toxic surfactants. Such surfactants would reduce the viscosity and interfacial tension at the oil/water interface of oil sludge creating an emulsion of oil and water that is safe to handle and process. A non-toxic biodegradable emulsion breaker could release the hydrocarbons from the water molecules allowing the emulsion to separate into water and hydrocarbon phases with hydrocarbon free particulate matter falling to the bottom. Once this is accomplished, the separated hydrocarbons can be fully recovered, blended with crude oil, and processed into fuel.

Typical sludge from oil tanks contains 85 to 95 percent hydrocarbons, 5 to 10 percent water, and up to 3 percent organics. Therefore, the recovery and reuse of these hydrocarbons would help to reduce crude oil consumption. Demonstrations have shown that this process can recover more than 90 percent of the hydrocarbon from oil sludge for either resale or reuse. However, the cost of non-toxic biodegradable surfactants is too high (about $8 per pound for oil recovery applications) since they are not manufactured in large quantities. To be competitive, they must be made at about $1 per pound or less.

Grant applications are sought to assess the feasibility of a bioprocess for the production of biodegradable non-toxic surfactants which can be used for hydrocarbon recovery from oil sludge, and which cost about $1 per pound or less. A sensitivity analysis must show that such costs are potentially achievable. Further research should have clearly defined objectives focused on those factors identified in the sensitivity analysis. Technology development and demonstration should take place in Phases II and III.

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6. 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:**

a. Gigabit Networks–In order to support the aggregation of multiple 100 megabit networks with advanced scientific applications, as well as applications requiring end-to-end gigabit bandwidths (i.e., where the bandwidth is maintained between applications running on separate hosts), the switching and trunking fabric of the network must efficiently operate at speeds ranging from gigabits to terabits, and must also be flexible in de-aggregating high speed tributaries. Grant applications are sought for the development and implementation of: (1) ultra high speed end system (host) gigabit interfaces (e.g. High Performance Parallel Interface (HIPPI 64)), (2) operating system and network protocol software to support end-to-end gigabit applications, (3) innovative approaches to the switching and trunking infrastructure, and (4) very high speed network monitoring, debugging, and analysis tools. Areas of interest include research on wave division multiplexing (WDM), Synchronous Optical NETwork (SONET), and other optical, electrical, and hybrid (optical and electrical) technologies, especially those supporting application level access to a capability which can securely and dynamically create virtual private networks from these network objects. Since DOE's work in this area compliments activities at the Defense Advance Research Projects Agency (DARPA), applicants must ensure that the proposed work is complimentary to or augments the gigabit to terabit research currently supported by DARPA.

b. Network Technologies–Development of 155 megabits per second (mbs) and gigabit networks will allow Internet speeds to increase by orders of 100 and 1000, respectively, from current speeds of 1.5 mbs. The utilization of this capability on the future 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:

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Network engineering, in which advanced tools 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; and (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.

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).

c. Application Demonstrations–Ultimately, the higher speed networks, described in subtopic 'a', and the tools and services, described in subtopic 'b', will be validated by their ability to handle advanced applications that are beyond the capability of the existing infrastructure. Grant applications are sought for application demonstrations that are important to the mission areas of the DOE, broadly classified as energy resources, national security, environmental quality, and science and technology that will aggressively utilize the technologies described in subtopics 'a' and 'b'. (Note that applications linked to any of the topics addressed in this document are within these mission areas.) Application domains of particular interest include: (1) scientific research, in which scientists and engineers across the country work with each other and access remote scientific facilities as if they were in the same building - such "collaboratories," combining video-conferencing, shared virtual workspaces, networked scientific facilities, and data bases, will increase the efficiency and effectiveness of our national research enterprise; (2) environmental monitoring, in which virtual worlds would be constructed to model and monitor defined ecosystems; and (3) climate research, in which scientists, researchers and policy makers examine the effects of proposed actions to the long-term evolution of our environment - models would become available to and usable by all interested parties.

Grant applications must include the following elements: (1) an application domain related to an important federal mission and recognized by the public as such, (2) an application that requires high-performance internetworking technologies and services, (3) networking concepts and technologies, embodied in the application testbed, which are extensible to other application domains and scalable to the future commercial Internet, and (4) interaction with the application community which will supply resources

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for the application-specific technologies component of the testbed.

d. 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 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 sub contractors 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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World Wide Web Information

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   http://www.es.net
2. National Coordination Office for High Performance Computing, Information, and Communications
   http://www.hpcc.gov
3. U.S. Department of Energy
   http://www.doe.gov
4. U.S. Department of Energy, Office of Energy Research
   http://www.er.doe.gov

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PROGRAM AREA OVERVIEW - BASIC ENERGY SCIENCES

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

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

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

A major objective of the BES program is to promote the transfer of the results of 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.

7. CHEMICALLY STABLE, MECHANICALLY RELIABLE SURFACE OXIDES FOR HIGH-TEMPERATURE CORROSION PROTECTION

Protection from corrosion and environmental effects, arising from deleterious reactions with gases and condensed products, is required to exploit the potential of advanced high-temperature materials designed to improve energy efficiency as well as minimize deleterious environmental impact. Ceramic films and coatings are candidates to protect the material on which they are formed or deposited (see reference 1); however, their brittleness has long been problematical, particularly for applications involving numerous or severe high temperature thermal cycles or very aggressive environments (see references 2, 3). This lack of mechanical reliability severely limits the performance or durability of alloys and ceramics in many high-temperature industrial and utility applications and places severe restrictions on the deployment of such materials.

The resistance to such reactions is best afforded by the formation of stable surface oxides that are slow growing, compact, and adherent to the substrate and/or by the deposition of coatings that contain or develop oxides with similar characteristics (see reference 1). The beneficial effects of certain alloying additions on the growth and adherence of protective oxide scales on metallic substrates are well known (see references 4, 5), but an understanding of the mechanisms by which scale properties and coating integrity (that is, corrosion resistance) are improved by compositional, microstructural, and processing parameters is lacking.

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This topic seeks to expand the scientific and technological approaches to improving stable surface oxides for corrosion protection in high-temperature oxidizing environments. The Department of Energy's goal is to establish a sound technical basis for formulating specific compositions and synthesis routes to produce materials with tough, adherent, stable, slow growing oxide scales or coatings that exhibit improved, elevated temperature, environmental resistance, which is crucial to the success of many advanced energy and processing systems.

a. Synthesis of Alumina Coatings for Improved High-Temperature Oxidation Resistance—Alumina (Al_2O_3), chromia (Cr_2O_3), and silica (SiO_2) can provide oxidation protection at very high temperatures (900°C) (see reference 1). Under appropriate conditions, these surface oxides are stable and slow growing and, if sound and adherent to the substrate, will provide oxidation resistance to the material on which they are grown or deposited. Because chromia shows significant volatility at temperatures greater than 1000°C, alumina or silica is preferred for high-temperature applications. This subtopic focuses on alumina. Alloys that form surface alumina upon exposure to an oxidizing environment (aluminides, FeCrAlY alloys, etc.) are attractive for applications in, for example, the heater, heat treatment, utility, and aero-propulsion industries (see references 6, 7). As an alternative to using materials that form surface alumina when exposed to an oxygen-containing environment, coatings of similar compositions could be used, either by directly depositing the appropriate elements or by aluminizing the substrate. Such coatings are finding increasing use as bond coats in thermal barrier systems for advanced aeronautical and land-based turbines (see reference 7).

Alumina coatings would circumvent the process by which the surface oxide is formed solely by thermal exposure and, possibly, could improve overall oxidation behavior. More importantly, the use of deposited alumina coatings allows microstructural manipulation of the alumina over a range not normally possible with thermal growth. Such an ability to tailor the structure of the alumina layers may or may not lead to improved oxidation resistance, but experimentation with such coatings should lead to important insights regarding the controlling factors involved in alumina growth and adherence. Grant applications are sought for innovative approaches to synthesizing adherent alumina coatings (1-5μm) on metallic substrates in order to either improve oxidation resistance at 1000-1300°C or use surface manipulation to grow alumina scales with low steady-state scaling rates and good adherence under thermal cycling conditions. Grant applications must demonstrate an awareness of current knowledge regarding protective alumina scales and coatings and show how such knowledge is used in: (1) developing the research plan, (2) avoiding duplication of previous efforts, and (3) setting criteria by which the protective ability of alumina scales and coatings will be judged. Grant applications must also provide details on the synthesis/processing method(s) and relevant experience with such.

b. Methods of Probing Buried Oxide-Metal Interfaces of Interest to High-Temperature Oxidation Protection—To be protective, an oxide layer must not only be chemically stable and provide a transport barrier between environmental species and substrate elements, but also remain adherent in the presence of stresses generated by product growth, thermal cycles, and impacts. Accordingly, much attention is being paid to phenomena at relevant oxide-metal interfaces that affect adherence (see references 8-14). Areas of interest include segregation of impurities and alloying elements, void formation, interface roughening, and the interactions among such processes. Each of these phenomena can affect oxide scale/coating adherence and the ultimate failure mode by which oxidation protection is lost. Methods for characterizing the evolution of interfacial structure and composition, resulting from exposure to high-temperature environments, would contribute greatly to understanding the factors controlling scale/oxide coating adherence. Currently such methods are *ex-situ* and destructive.

Methods which can probe buried metal-oxide interfaces would avoid complications associated with destructive examination and allow the evolution of interfacial processes to be monitored on the same specimen. If such techniques could be conducted *in-situ* during elevated temperature exposure, their value to understanding scale adherence becomes even greater: the need for multiple specimens to establish the time-dependence of the interface reactions could be avoided, and interfacial processes operating at constant temperature could be separated from those triggered during thermal transients. Ultimately, the application of *in-situ*

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methods to examine such buried interfaces could lead to development of diagnostic probes for real-time use. Grant applications are sought to develop methods for probing the chemistry and/or structure of oxide-metal interfaces of relevance to protective oxide scales or coatings (that is, alumina, chromia, or silica layers, about 1-5μm in thickness, on appropriate substrates). Applications must provide proof-of-principle by satisfying clearly stated objectives. Proposed approaches should be innovative in the selection of techniques and in the application to a particular problem.

c. Novel Approaches to Measurement of Scale Growth on Alloys Undergoing High-Temperature Deformation—Stresses arising from oxide growth, thermal cycling, or external loading can affect high-temperature oxidation rates by influencing the diffusional processes that control the growth of oxide scales on metals and alloys (see reference 2). Conversely, the development of a scale can affect surface stress evolution and the mechanical behavior of a particular material system. The coupling between stress and the diffusional processes associated with scale growth is fairly well understood in principle, but direct measurements under appropriately controlled conditions are lacking. Experimental systems that allow for continuous determination of scale growth rates on alloys undergoing deformation are needed to understand the synergistic effects of stress and oxidizing potential on diffusion/scale growth, to understand associated phenomena affecting oxide reliability, and to test models based on present understanding. Although systems do exist for mechanically testing materials in high-temperature environments, innovative methods are needed to combine these systems with real-time measurements of scale growth. This capability would be a significant improvement over approaches in which high-temperature exposures under stress have to be periodically interrupted for scale thickness measurements or in which a set of specimens has to be repeatedly exposed under load.

Grant applications are sought to develop a system for conducting real-time measurements of scale thickness on an alloy undergoing mechanical loading in a well-controlled high-temperature gaseous environment. Phase I should: (1) demonstrate proof-of-principle for scale thickness measurement based on measurements using unstressed specimens, and (2) provide a design assessment which demonstrates the feasibility of integrating this measurement with a mechanical loading system and an environmental chamber equipped to handle various reactive gas atmospheres at high temperatures (up to at least 1100°C). The systems must be applicable to oxide scales that form, and are stable, on alloys at temperatures in excess of 800°C. Approaches which demonstrate uniqueness, innovation, and accuracy will receive the highest consideration. Other (less important) criteria include cost and adaptability (for example, to incorporate other analytical tools).

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8. INTERMETALLIC ALLOYS FOR STRUCTURAL USE

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

a. Alloy Design of Nickel and Iron Aluminides—Several nickel and iron aluminide alloys have been developed recently for structural uses at elevated temperatures and hostile environments. These alloys possess improved ductility and toughness at ambient temperatures and superior strength at elevated temperatures. The mechanical and metallurgical properties of these aluminide alloys can be further improved by alloy design efforts. Grant applications are sought to: (1) reduce environmental embrittlement in iron aluminides at ambient temperatures (moisture- and hydrogen-induced embrittlements have been alleviated but not completely eliminated in current Fe_3Al and FeAl alloys); (2) improve creep properties of Ni_3Al and iron aluminide alloys by inhibiting grain-boundary sliding in nickel aluminide alloys and lowering diffusion processes in iron aluminide alloys; (3) improve machinability of aluminide alloys which are not easily machined, possibly due to high work hardening rates during machining and cutting (machinability of the alloys must be carefully characterized, and new cutting tools identified for economical machining); (4) develop wrought nickel aluminide alloys with adequate hot fabricability via control of minor alloying additions (<1 atomic percent); (5) improve impact resistance of iron aluminide alloys (these alloys possess limited impact

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resistance at ambient and elevated temperatures, even though they have adequate tensile elongations in conventional tensile tests); and/or (6) develop near-net shape processing techniques such as reaction syntheses and direct fabrication (techniques should include material processing procedures to control microstructures and textures, as well as alloy design and property improvement through control of minor alloy additions).

b. Chromium-Based Laves-Phase Intermetallic Alloys for Structural Applications—Laves phase materials represent an abundant class of intermetallic alloys with possible high-temperature structural applications. Chromium-based Laves-phase alloys containing refractory elements (Cr_2Nb, Cr_2Zr, Cr_2Hf, etc.), have unique properties which make them particularly attractive: high melting point, excellent high-temperature strength and creep resistance, and adequate oxidation resistance. Despite these useful properties, low-temperature brittleness has limited their potential use. Grant applications are sought to: (1) develop processing techniques to produce Cr-based Laves-phase alloys in bulk quantities with low levels of trace impurities and minimum micro- and macro-cracks and cavities; (2) design Cr-based Laves-phase alloys with improved fracture resistance by promoting deformation twinning through controlling crystal structure, adding ductile second-phase particles to bridge cracks, refining grain structure, and controlling grain-boundary chemistry (little is known about the effect of alloying additions on the mechanical and metallurgical properties of these Laves-phase intermetallics); and/or (3) develop two-phase intermetallic alloys based on Cr-Cr_2X (X= refractory elements) which do not exhibit the hard, brittle behavior found in single-phase Cr_2X intermetallics at ambient temperatures (binary Cr-Cr_2X phase diagrams indicate the existence of stable two-phase fields, based on the soft Cr-rich solid solution and the hard Cr_2X phase, which suggests the possibility of developing strong, tough, and oxidation-resistant two-phase alloys through the control of microstructures and alloy additions).

c. Development of Boron-Doped Mo_5Si_3-Based Intermetallic Alloys—Mo_5Si_3 is the most refractory compound in the Mo-Si binary diagram, with a melting point of 2180°C. Recent studies indicate that the oxidation resistance of this silicide can be dramatically improved by alloying with a few weight percent of boron. The boron additions promote the formation of glassy borosilicate scales which protect the base metal from excessive oxidation at elevated temperatures. The excellent oxidation resistance, in combination with superior creep resistance at elevated temperatures, makes B-doped Mo_5Si_3 alloys promising for structural applications at temperatures above 1200°C. The major obstacle that keeps these alloys outside the realm of engineering materials is their poor fracture toughness at ambient temperatures. Brittle B-doped Mo_5Si_3 alloys are difficult to prepare and fabricate, and their mechanical properties are sensitive to trace impurities, such as oxygen. In addition, the metallurgical factors that control fracture toughness at ambient and elevated temperatures are not well understood. Grant applications are sought to develop: (1) innovative processing and synthesis techniques for B-doped Mo_5Si_3 alloys with high purity and good quality, in sizes large enough for mechanical and physical property characterization; and (2) methods for enhancing the fracture toughness of the B-doped Mo_5Si_3 alloys (e.g., by promoting deformation modes).

Grant applications are also sought for new alloy designs for B-doped Mo_5Si_3 alloys. Alloying behavior with different elements should be explored using both fundamental calculations and alloying experiments. It is important to determine the effectiveness of alloying elements in the silicide alloys as well as their effect on thermophysical and mechanical properties as a function of temperature (up to 1400°C). The alloying approach must result in significantly improved high-temperature creep resistance, room-temperature impact resistance, and oxidative stability.

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9. MOLECULARLY ENGINEERED NANOSCALE MATERIALS

In this era of rapid technological growth, performance issues impact the choice of materials for ever more demanding applications. In many instances, inherent properties limit the use of new materials as replacements for more traditional materials. However, significant improvements in materials properties can be realized through microstructure modification. For example, thermal degradation of nylon precludes its use at high temperatures, but integrating lamellar ceramic phases with the polymer imparts both increased mechanical strength and a marked improvement in thermal stability. Since tailored nanoscale architectures are known to significantly enhance material properties such as ion or molecule transport, ion trapping efficiency, mechanical strength, thermal stability, and catalytic activity, ordered mixed polymer and polymer-derived ceramic phases are likely candidates to replace more traditional materials. The anticipated development of new molecularly engineered materials should have significant implications for Department of Energy applications which require improved thermal insulants, more efficient petroleum chemistry catalysts, ion exchange/ion trapping materials for waste isolation, or materials with modified electronic properties.

This topic is focused on designing new (or refining existing) solution-based processing routes in which a surfactant mediated process involving molecular self-assembly is used to derive a target structural architecture. The research must include development of processing methods and correlation of processing parameters with inherent microstructure and properties. Research efforts should involve a multidisciplinary team of scientists and engineers, and a cogent DOE materials application must be explicitly defined. **Grant applications are sought only in the following subtopics:**

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a. Ceramic/Void Composite Synthesis—Grant applications are sought to control porosity in oxide-based ceramic materials using an environmentally benign self-assembly process. In this process, tailored surfactant molecules would be developed which undergo reorganization in a fluid carrier containing a ceramic precursor. Nucleation and growth of a ceramic phase around the surfactant matrix would then produce ordered porosity in the ceramic matrix following surfactant burnout at high temperatures. Such materials would have applications as shape selective catalysts for the petroleum refining industry. Also, as membrane materials, they could be used at significantly higher temperatures for gas separation applications and coolant water purification at electric power generating plants. Areas of research interest include: (1) imparting nanoscale ordered anisotropic pores in a ceramic; (2) imparting nanoscale ordered isotropic pores in a ceramic; (3) imparting enhanced chemical and thermal robustness; (4) grading the pore density distribution normal to the surface; and (5), controlling pore interconnectivity.

b. Polymer Matrix Composite Synthesis—Grant applications are sought to develop processing methods for forming a polymer matrix monolith containing a second polymer or ceramic phase resident in a well-ordered nanoscale architecture. Prospective synthesis routes include using an ordered ceramic phase to orient the polymer matrix, and using self assembly of polymer precursors to form an ordered pore nanostructure into which the second phase can percolate. In developing the processing method, the research should also seek to understand: (1) the nature of the interface between the two phases and how processing parameters influence that interface; (2) the deviation from bulk properties of both the matrix and the filler phase material; (3) the relationship of polymer matrix physical properties, such as the glass transition temperature (T_g), to the second phase architecture; and (4) the stability of the interface upon application of an applied stress (thermal, mechanical, chemical).

c. Modeling Surfactant Self-Assembly—A fundamental understanding of molecular self-assembly and of how processing parameters influence the assembly process is inherent to the materials processing activities described in this topic. In solution templating reactions, fixed amounts of chemical precursors are introduced into a carrier solvent at known temperature and pressure for a prescribed time. Depending upon the processing parameters, a particular ordered nanoscale architecture or mixture of architectures (e.g., lamellar, hcp, cubic) results. By varying processing parameters and performing microstructural analysis, a phase diagram can be developed. Grant applications are sought to develop molecular models for identifying regions of phase space where particular nanoarchitectures are stable. Initial studies should focus on a three component system consisting of surfactant, hydrophobic liquid, and hydrophilic liquid phases. Simulations as a function of composition, temperature, and pressure are required. Grant applications must address the development of appropriate interaction potentials to model the self-assembly process, and the effort must be integrated with an experimental segment to verify predictions from the code. The effects of temperature and pressure on the derived equilibrium phases could then be pursued.

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10. PROCESSING AND CHARACTERIZATION OF THIN FILM PHOTOVOLTAIC MATERIALS AND DEVICES

This topic provides small businesses with an opportunity to carry out substantially novel research on the growth of thin-film photovoltaic materials and on the formation of device structures. Thin-film photovoltaics hold the promise for significant cost reduction and, hence, greater potential for large scale commercialization. Materials and devices of interest include thin-film silicon, II-VI materials like cadmium telluride (CdTe) and its ternary analog copper indium diselenide ($CuInSe_2$), and thin-film photoelectrochemical cells such as dye-sensitized TiO_2 films. Each of these materials and device technologies presents some unique issues that need to be addressed before their full potential can be realized in terms of conversion efficiency, reliability, reproducibility, increased processing safety, and cost. For example, in the case of thin-film silicon, the issues are growth on low-cost substrates, enhancement of grain-size, grain boundary passivation, and effective light trapping. The primary issues for $CuInSe_2$ are process reproducibility in module manufacturing and narrowing the gap between cell and module efficiency. In the case of CdTe, the issues are reliability, low resistance contacts of p-type materials, and the environmental sensitivity of cadmium. The key issues for dye-sensitized TiO_2 thin-film solar cells concern the growth of nano-structure thin film TiO_2 with appropriate crystal structure, and novel dye-systems that provide efficient energy transfer and long-term stability. The development of better process diagnostics during growth would be of generic value to thin films to monitor critical parameters such as layer quality, strain relaxation, and thickness.

Grant applications should be submitted for consideration under this topic only if the research represents a significant advance in materials or in processing that will lead ultimately to high-quality, thin-film photovoltaics at costs which are competitive with present day energy courses. Grant applications will be declined if they are: (1) limited to a minor improvement of a material or process, or (2) limited to data collection or a paper study. **Grant applications are sought only in the following subtopics:**

a. Silicon Thin Film—Grant applications are sought on improved performance of thin (30 micron or less) film silicon cells on low-cost substrates. Specifically, grant applications should focus on the development and use of low-cost substrates that will not cause device degradation by becoming a source of impurities during subsequent film fabrication. Results should be provided in terms of actual cell fabrication and efficiencies of more than 10 percent (for cells with thin Si layers). Novel approaches to enhancement of grain size, grain boundary passivation, and light trapping will be of great interest.

b. Copper Indium Diselenide (CIS) and its Alloys—Grant applications are sought for improved film fabrication of $CuInSe_2$ and its alloys with an aim toward lower cost and more robust, large-area processes. Although CIS devices are the most efficient thin films (17.6 percent), they are not commercially available because manufacturing is difficult. Grant applications are invited on innovative processes that could be adopted for making near state-of-the-art CIS cells/modules while improving the probability of successful manufacture. Nonvacuum alternatives and/or simplified processes with self-limiting reactions are of particular interest. Improved materials are also of interest.

c. Cadmium Telluride (CdTe)—Grant applications are sought for the development of reliable, low-cost contacts to n-CdS/p-CdTe polycrystalline thin film cells. Contacts on materials and devices should be fabricated and validated through stability testing. Cells must produce near state-of-the-art efficiencies (more than 14 percent). Innovative approaches to reduce or eliminate the various steps (CdTe post-deposition treatments and etches) and simplified methods are of particular interest.

d. Dye-sensitized TiO_2 Thin Film Photoelectrochemical Cells—Grant applications are sought for the development of reliable efficient photovoltaic materials and devices based on dye-sensitized nano-structure TiO_2 thin film in an electrochemical solar cell configuration. Some of the issues of concern are: nano-structure material deposition; highly efficient dye-sensitizers; new redox couple in the electrolyte; possible all solid state devices; stability behavior of this type of cell; and optimization of materials and device parameters.

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11. INNOVATIVE R&D FOR ELECTRIC VEHICLE TECHNOLOGIES

The ability to advance the widespread commercial use of electric and hybrid vehicles has been limited by the performance of power sources and by the excessive cost of the vehicle to the buying public. Therefore, the Department of Energy (DOE) Advanced Automotive Technologies Program is interested in identifying and developing innovative concepts for batteries and fuel cells that will improve performance and life, and reduce the cost of the vehicles. Among the technologies under development are rechargeable batteries and proton-exchange membrane (PEM) fuel cells. Applications should show how the proposed innovations will result in significant advances over the state-of-the-art technologies. **Grant applications are sought only in the following subtopics:**

a. Alternative Electrode Materials for Rechargeable Batteries—Grant applications are sought to develop rechargeable batteries, using electropositive and electronegative materials other than lithium metal or carbon intercalation compounds, with capacities greater than 375 milliampere hours/gram. The research and development effort must include appropriate steps to fabricate working cells with the alternative materials and must show that the cells are capable of reasonable energy and power performance as well as adequate cycle and calendar life. The proposed batteries should avoid the use of strategic, high cost materials to minimize the eventual product cost, should not contain materials that are potentially harmful to the environment, and should be completely recyclable. The final product should show significant improvements over currently used nickel metal hydride rechargeable batteries, and costs should be estimated for small consumer battery applications, as well as for large cells in electric vehicles or hybrid electric vehicles.

b. Polymer Electrolytes for Batteries—Polymer electrolytes are attractive candidates for battery applications because of their solvent-free nature, excellent flexibility, good adherence to electrodes, and the ability to form thin films. Lithium/polymer batteries are currently of interest to the DOE for advanced consumer applications and for electric vehicles. However, polymer electrolytes for battery applications are limited by their low ionic conductivity. Reactivity with lithium is also a problem. Grant applications are sought to develop polymer electrolyte systems having good chemical and thermal stability, and ionic conductivity greater than 10^{-3} Siemans/cm.

c. Polymer Electrolytes for Proton-Exchange-Membrane (PEM) Fuel Cells—Significant advances are necessary to improve the performance and reduce the cost of electrolytes in fuel cells. In PEM fuel cells, water management is a significant issue. Too much, too little, or

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nonuniform distribution of water in the membrane limits fuel cell performance. For PEM fuel cells that operate on hydrogen produced from reformed fuel, another disadvantage is poisoning of the cathode catalyst due to trace levels of carbon monoxide. Higher operating temperatures, not possible using current membranes, may eliminate both of these disadvantages. Grant applications are sought to develop new polymer membrane systems which demonstrate improved performance over the state-of-the-art at 80-90°C, or membranes capable of operation at 120-200°C to eliminate CO poisoning and alleviate water management problems in PEM fuel cells.

Direct methanol PEM fuel cells are also being developed because they eliminate the need for an external reformer, reducing system weight and cost. However, methanol diffusion through current membranes is too large (approximately 10^{-2} cm^2/s), causing loss of fuel and poisoning of the cathode. Grant applications are solicited for solid state electrolytes which have proton conductivities of 10^{-3} Siemans/cm or greater and which are impermeable to methanol.

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* See Section 7.1

12. ADVANCED DRILLING SYSTEMS - COMPUTATIONAL ALGORITHM AND SOFTWARE DEVELOPMENT

The Department of Energy supports research and development of advanced drilling systems, devices, and technologies. A National Advanced Drilling and Excavation Technology program has been initiated by federal agencies to coordinate their efforts in developing new and advanced drilling technologies, in addition to aligning these efforts with the needs of U.S. industry. One area identified by this ongoing effort is advanced software for optimizing the drilling process.

Using today's computing power, in both hardware and software, the development of advanced modeling and simulation techniques for drilling operations could result in field-applicable computational tools that will significantly benefit drilling operations worldwide. These tools would significantly decrease the cost of drilling and increase the efficiency with which wells are drilled. Moreover, the fundamental research resulting from these grant applications should be applicable to fracture predictions in other heterogeneous systems ranging from micro machinery to geologic structures, regardless of scale.

The Federal National Laboratory system is an invaluable resource for rock mechanics, geologic, and drilling data that can serve as input to any decision making or simulation models developed in response to this topic. Additionally, several state funded and/or university-based computer modeling and simulation centers have begun to offer services or co-funding for this type of work.

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Any simulation or modeling tools developed should be able to be run on a variety of different computer operating systems and architectural platforms. **Grant applications are sought only in the following subtopics:**

a. Advanced Rig Decision-Making Software—The myriad of rig instrumentation sensors already sending data to the driller and drilling engineer is almost too complex. An abnormal reading in one or more of the many readings displayed on the video screen at the drillers station, and in the drilling engineer's office, is not unusual. It is often difficult to ascertain what is happening on the rig, and in the hole, based on the displayed data. Grant applications are sought to develop expert system software that analyzes incoming sensor data, interprets it to determine the most probable status of the drilling process, and then makes recommendations on how to improve the ongoing process. These "smart" systems should be extremely useful in increasing the efficiency with which wells are drilled, thereby reducing costs.

b. Advanced Simulation Models—The logistical difficulties, expense, and risk, of educating drillers are formidable barriers to developing a competent work force for the U.S. drilling industry. Grant applications are sought for advanced, computer-based models which can simulate all aspects of drilling operations for hard-rock, high-temperature, high-pressure wells and which can be used not only in training personnel but also in helping to mitigate potential problems encountered during drilling operations. Models must contain several scenarios simulating a variety of drilling operation anomalies. Additionally, the models must be amenable to updating, so that additional scenarios can be incorporated as sensor and situational data become available from a variety of sources.

c. Computational Geosciences - Rock Fracture Simulations Under Drilling Conditions—Methods of rock drilling, boring, and comminution are likely to be improved if empirical studies of tool actions and attendant rock response were complemented by proven computational simulations of interactions between drilling tools and rock. Credible simulations must reflect the dominant mechanisms of rock deformation and failure at the grain scale as well as an understanding of the transition from grain-scale rock fracture to the development of discrete macroscopic fractures and chip formation. Grain-scale failures are especially important in compression, where friction must be considered and where bulk failure is not necessarily determined by the stability of a single critical flaw but by the multiplication, growth, and interaction of many small cracks between crack nucleation and the formation of major discrete fractures. Grain scale failures and macroscopic fracture development are complicated further by the degree of rock heterogeneity, pore collapse, pore pressure, chemo-mechanical effects, and the influence of loading rate.

Grant applications are sought which address the following combined tasks: (1) development of a conceptual model for grain scale rock fracture and attendant discrete, macroscopic rock fracture development under conditions of drilling or other processes of rock disintegration, including hybrid techniques; (2) development of a three-dimensional numerical simulation method based on the model developed in task (1) and on experimentally measured physical rock properties; and (3) application of the combined conceptual model and numerical simulation method to several case studies of hard rock drilling operations (field or laboratory) for realistic evaluations of predictive capabilities.

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World Wide Web Information

1. Geothermal Resources Council
   http://geothermal.org
2. U.S. Department of Energy, Geothermal Energy Technical Site
   http://doegeothermal.inel.gov
3. Sandia National Laboratories, Energy and Environment Sector, Geothermal Research Department
   http://www.sandia.gov/eesector/gs/gt/geothermal.html

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* See Section 7.1

13. MEMBRANES FOR ADVANCED INDUSTRIAL SEPARATION TECHNOLOGIES

Industrial separations recover, isolate, and purify products in virtually every industrial process. Pervasive throughout industrial operations, conventional separation processes are energy intensive and costly. Separation processes represent up to 70 percent of capital and operating costs in a number of major industries. They account for 45 percent of all the process energy used by the chemical and 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 (DOE) supports high-risk, innovative separation technology development. 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 membranes require greater thermal and chemical stability, greater reliability, improved fouling and corrosion resistance, and higher selectivity. The objective is better performance in existing industrial applications as well as opportunities for new applications. **Grant applications are sought only in the following subtopics:**

a. Membrane Materials with Improved Properties—Grant applications are sought to develop inorganic, organic, composite, and ceramic membrane materials with improved properties in one or more of the following areas: separation by chemical differences, separation by size differences, capability to reverse separation order, separation by diffusivity differences, oxygen separation/oxidative chemistry, lower cost small volume oxygen production, oxidation/dehydrogenation reactions, and membrane reactors.

b. Enhanced Membrane Separation in Process Streams—Grant applications are sought to enhance separation capabilities of membranes used in industrial process streams. The following areas are of interest: improved regeneration technology, hydrogen separation/recovery, inert gas removal, isomer separation, aromatic/non aromatic separations, sulfur removal from gas/liquid fuels, removal of trace metals (e.g., catalyst contaminants).

c. Membrane Separations for Dilute Streams—Grant applications are sought for improved or novel approaches in developing cost-effective membrane separations for dilute streams of 3-5 percent or less solute(s) to be removed or recovered. Dilute streams may include: paraffins/olefins, H_20/ethanol, CO_2/natural gas, sulfur/natural gas/liquified petroleum gas/oils, SO_2/air, organics/air, organics/water, metals/water, metals, crude oil, and solid particles in air/water.

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a. High-Density, Multigene Assay Systems—Grant applications are sought that employ nanotechnology designs to develop multigene assays for plants and non-medical microbes. Research should focus on multigene identification and monitoring strategies that addresses some important aspect of the national energy picture involving the use of plants or non-medical microbes. The focus should be on the utility of the series of genes being assayed rather than on engineering incremental improvements in the instruments used to create the high-density array or detection system. The proposed research should span the proof-of-concept phase to the application of the particular genes assayed to an energy relevant system.

Grant applications must also address: (1) the novelty and utility of the series of short oligonucleotides or longer gene-length segments to be arrayed on a chip, (2) the realization potential of the chip design or high-density array in terms of utilizing available genomic sequence data, (3) a discussion on informatics and how data generated from the gene chip can be handled and analyzed, (4) the significance of the chip to plant and microbial research as well as to the related energy advantage, and (5) the outlook for economic benefits.

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PROGRAM AREA OVERVIEW - BIOLOGICAL AND ENVIRONMENTAL RESEARCH

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

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 national laboratories to determine biological structure and how it relates to function at the molecular and cellular level.

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

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

15. 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. Technologies that Support DNA Sequencing and DNA-Based Diagnostics—Increased use is being made of DNA sequencing in biotechnology, microbiology,

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medical applications, and environmental applications. Grant applications are sought for improvements in DNA sequencing technologies so that an already-determined DNA sequence from one species (e.g., of microbe) could be used to determine the homologous sequence from a taxonomically-related species. Applications are sought that could exploit this approach for polymorphism detection in human DNA sequences. Applications must significantly improve, integrate, or automate steps associated with large-scale DNA sequencing or DNA-based screening. Developments might include: 1) improved approaches to comparative sequencing; 2) determination and mapping of sequence variations or polymorphisms between homologous genomic regions from humans, or related species of environmental microorganisms; 3) automation of handling and processing of the results from DNA sequencing instruments.

b. Genome Sequence Quality Assurance/Quality Control—The quality of genomic sequences deposited in public databases is critically important for the success of the Human Genome Project (HGP). It is generally agreed that HGP should try to attain a standard of accuracy such that no more than 1 base in 10,000 is miscalled. Grant applications are sought for methods to assess the accuracy of sequenced DNA from any source with particular emphasis on human and microbial DNA sequences. Both experimental and computational methods, as well as methods for assessing the accuracy of DNA fragments assembled into contigs (from cosmids, bacterial artificial chromosomes, or P1-artificial chromosomes) using "shotgun" or "directed" sequencing approaches, are of interest. Other areas of interest include quantitative assessments of sequence accuracy of archived data and computationally derived assessments of accuracy as a function of map position.

c. Novel Microarray Approaches for Biosensors, Diagnostics, and Molecular Interactions—Considerable activity is underway to bring to market technologies involving microarrays of DNA oligonucleotides for polymorphism detection, resequencing, and DNA-based diagnostics. Grant applications are sought for comparable technologies involving microarrays of non-nucleic acid gene products that can potentially be used in assessing bio-active molecules to indicate metabolic status, biochemical processes, or exposure to external materials. Developments of interest include arrays of uncharacterized gene products (for functional analysis), arrays of gene products to assess interactions with other biomolecules (including nucleic acids), or arrays of gene products to assess physiological states. Applications should include discussions of how output signals or data will be processed so that successful microarray technologies could potentially be incorporated into automated systems.

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2. Genequiz
   http://columba.ebi.ac.uk:8765/ext-genequiz
3. Genome DataBase
   http://gdbwww.gdb.org
4. Genome Sequence DataBase at the National Center for Genome Resources
   http://www.ncgr.org/gsdb/gsdb.html
5. Human Genome Project Information
   http://www.ornl.gov/hgmis
6. Protein Data Bank
   http://www.pdb.bnl.gov
7. PUMA: Phylogeny, Metabolism, Alignments
   http://www.mcs.anl.gov/home/compbio/PUMA/Production/puma_graphics.html
8. The National Center for Biotechnology Information
   http://www.ncbi.nlm.nih.gov
9. The Nucleic Acid Database
   http://ndbserver.rutgers.edu

* See Section 7.1

** Available from Human Genome Management Information System, Oak Ridge National Laboratory, 1060 Commerce Park, MS-6480, Oak Ridge, TN 37831. Telephone 615-576-6669.

16. MEDICAL APPLICATIONS

The Department of Energy (DOE) Medical Applications program covers a broad range of energy-related technologies including nuclear medicine research. DOE is interested in innovative research involving nuclear medicine technologies to facilitate and advance the current state of diagnosis and treatment of human disorders. Current areas of research in nuclear medicine focus on the development of: (1) radiolabeled molecular probes as radiotracers to study *in vivo* chemistry, metabolism, cell communication, and gene expression in normal and disease states; (2) new radionuclide-imaging systems; and (3) new boron-labeled compounds targeted for use in neutron capture therapy of cancer. **Grant applications are sought only in the following subtopics:**

a. Radiotracer Development and Molecular Radiopharmaceutical Therapy Compound Development Technologies—Grant applications are sought for the development of: (1) radiolabeled compounds that could have applications as radiotracers for radionuclide imaging technologies such as single photon emission computed tomography and positron emission tomography; and (2) radiopharmaceuticals for targeted molecular therapy. Radiochemical, synthetic, and molecular approaches should be given consideration in developing molecular medicine technologies capable of providing a product for nuclear medicine use.

b. Boron Neutron Capture Therapy Compound Development—Grant applications are sought for boron-labeled compounds that are capable of concentrating in tumor cells *in vivo* and delivering lethal radiation after neutron irradiation.

c. Advanced Imaging Technologies—Grant applications are sought for new, sensitive, high resolution instrumentation for radionuclide imaging, which advances the application of radiotracer methodologies for imaging molecular biology, including cell communication and gene expression *in vivo*. Areas of interest include development of new detector materials, detector arrays for three-dimensional imaging, software development for rapid data processing, and image reconstruction.

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17. ATMOSPHERIC MEASUREMENT AND SAMPLING 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. The following subtopics focus on these needs. Subtopics 'a' and 'b' concern the development of sensor and launch systems, respectively, for balloon sondes. Subtopic 'c' concerns the development of new radiometric instruments. Finally, subtopic 'd' concerns the development of sensors for carbon flux measurements.

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. Automatic Launcher System for Balloon Sondes— A cost-effective capability is needed to launch a series of balloons with sensors over periods of time, i.e., a day or days, at unattended locations. Grant applications are sought to develop a balloon launch system for unattended operations with a capability to launch a minimum of eight sondes in succession, acquire the data from each flight, and make the data available for network data transfer to a centralized data acquisition facility. Grant applications that make only incremental improvements to existing technologies will be declined.

b. High Accuracy Sensors and Automatic Launcher System 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 such 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. 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 be packaged in an infrangible structure suitable for routine use in general aviation airspace. Sensors must recover quickly from possible wetting by clouds and rain. Utilization of the Global Positioning System is required

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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.

c. Radiometric Instrumentation—Measurements of shortwave solar radiation (0.3 to 3.0 micrometers) and thermal radiation (3 to 100 micrometers) provide necessary information about the chemical and physical state of the atmosphere and earth's surface. Current broadband solar instruments include pyranometers, pyreheliometers and shadowband radiometers while solar spectral instruments include scanning filter photometers, shadowband radiometers, and spectroradiometers. Thermal instruments include broadband infrared radiometers, interferometers, and grating spectrometers. Grant applications are solicited to develop radiometric instrumentation or radiometer components that: (1) improve current performance of broadband shortwave radiometers (e.g., it is desirable to achieve consistent one percent accuracy by eliminating the need for domed covers and/or other sources of uncertainty such as angle of incidence, temperature, pressure, and humidity effects on detectors, optical components, and windows); (2) significantly reduce drift, poor angular response, dome and window contamination (e.g., dust and water) errors, nighttime offsets, thermal imbalance errors, leveling sensitivity or other sources of error; (3) significantly reduce the cost of ancillary equipment such as solar seekers and trackers without degrading performance; or (4) extend the range of low-cost spectral instrumentation into the ultraviolet B spectrum (0.28 to 0.32 micrometers) and near infrared (2 to 50 micrometers) regions. Applicants may focus on critical components and ancillary equipment for radiometers including detectors, radiation standards and calibration methods, filter systems and monochromators, and solar tracker/seekers. Applications that make only incremental improvements to existing radiometric devices will be declined.

d. Sensors for Measurements of Terrestrial Carbon Changes—Measurements to detect significant quantities of carbon sequestration by natural vegetation and ecosystems are required from durable instruments to support atmospheric and climate research. Grant applications are sought to develop a remote and ground-based sensor to detect annual net carbon change of terrestrial vegetation for large areas. Spatial measurements must provide aggregate estimates of terrestrial carbon changes to an accuracy of 10-50 tons per square kilometer. Unattended and/or remote operation for prolonged periods of time (nominally weeks) without degradation of the measurement must be demonstrated. The design of the system must be durable in the full range of normal environmental conditions, e.g., dust, rain, snow, etc. The sensor must be applicable for the following vegetative surfaces: forests, grasslands, shrub lands, agricultural lands, and wetlands. The interest is in measurement systems which are different from, or which substantially augment, existing eddy flux (covariance) measurements. Applications that demonstrate a potential for only incremental improvements to existing measurement systems will be declined.

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* See Section 7.1

18. ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

Characterization of subsurface, atmospheric, and oceanic environments is a key element of several Department of Energy (DOE) research efforts designed to analyze the transport, fate, and human and environmental health effects of energy materials and wastes. This topic concerns innovative technologies to advance environmental monitoring capabilities. Monitoring in this context means long-term measurement of biological and physicochemical properties of natural systems with low-maintenance or autonomous sensors and equipment. Instrumentation should consist of rugged, field-capable sensors that provide real-time sensing. Monitoring will be a critical assessment and control activity in designing for sustainable development, as well as for future, pollution-free, zero-discharge, environmentally benign energy systems. Subtopics 'a' and 'b' relate specifically to the monitoring and remediation of the subsurface environment, while subtopics 'c' and 'd' concern environmental monitoring in general.

Grant applications must include bench tests of critical technologies. Critical technologies are those components, materials, equipment, or processes that significantly limit current capabilities in the specific subtopic area. Applications that propose only incremental improvements or enhancements to existing technologies will not be considered. Grant applications in all subtopics must describe, in the technical approach or work plan, the purpose and benefits of any proposed teaming arrangements with government laboratories or universities. Applications for all subtopics should provide information supporting 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. Contaminant Availability— The availability of contaminants to humans and other environmental receptors plays an important role with respect to human health and ecological risks associated with many contaminated soils, sediments, and aquifer materials. In many cases, innovative treatment technologies such as bioremediation may not remove all of the contamination from the environmental media, particularly if contaminants are strongly sorbed or sequestered in aged soils or sediments. Nonetheless, the treatment may still be effective in decreasing the risk to acceptable levels by causing a significant reduction in the bioavailability of the residual contaminant fraction. Consequently, from a risk assessment perspective, it is of crucial importance to determine the availability of contaminants to humans and other environmental receptors.

Grant applications are sought to: (1) develop methods, processes, materials, or equipment for determining the availability of soil-bound contaminants to groundwater via leaching—proposed technologies must simulate natural leaching conditions and must provide highly sensitive data on leaching or desorption rates; (2) develop methods, processes, materials, or equipment for determining the availability of soil-bound contaminants to plants and/or the plant rhizosphere, for the purpose of better predicting and optimizing phytoremediation of contaminated soils, wetlands, and groundwater—proposed methods must be more rapid than indirect plant availability protocols such as standard seed germination and plant growth tests; or (3) develop methods, processes, materials, or equipment for determining the availability of soil-bound contaminants to indigenous or introduced microorganisms, for the purpose of better predicting and optimizing bioremediation of contaminated soils, wetlands, and groundwater.

All technologies proposed for this subtopic must address organic or inorganic contaminants of concern to DOE and other Federal agencies. In addition, proposed technologies must be able to determine contaminant availability in a fast,

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cost-effective, and reproducible manner. While initial technology development may address fundamental issues related to contaminant availability, it should be recognized that successful commercialization may ultimately require endorsements from regulatory agencies. Minor adaptations of existing methods, processes, materials, or equipment will not be considered responsive to this subtopic.

b. Remediation Analysis—Subsurface remediation technologies have expanded steadily and improved over the last decade. Soil washing, solvent extraction, bioremediation, vapor extraction, chemical treatment, and forms of thermal treatment have grown by 44 percent at Superfund sites since 1982. However, the effectiveness of these technologies often cannot be assessed in a timely manner because of inadequate site analysis prior to remediation, lack of sensing and process-control techniques, and difficulty in obtaining uncompromised samples from remediation sites, especially subsurface ones. Grant applications are sought to develop: (1) innovative methods, processes, materials, and/or equipment for assessing the efficacy of remediation actions (proposed technologies should indicate the effectiveness of remedial activities in relation to natural recovery processes occurring at untreated sites, with comparable environmental insults); (2) process control systems, materials, components, or equipment that will improve remediation effectiveness (proposed technologies must significantly reduce remediation duration and/or costs through advancements in methodologies used to monitor, analyze, or control the remediation process); (3) novel methods, field-data display techniques, three-dimensional imaging equipment, and software, to precisely determine, display, and/or track operations to allow discrimination between closely spaced but geologically dissimilar samples.

Techniques proposed for this subtopic should not require regulatory approval for implementation. Minor adaptations of readily available materials or hardware for such use will not be considered responsive to this subtopic.

c. Biosensors and Genetic Probes—There is a need for sensitive, accurate, and real-time monitoring of biological organisms and processes and physicochemical parameters in the environment. Uses for such environmental measurement capabilities range from bioremediation of subsurface hazardous waste sites to waste-water analysis. 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 environmental applications. Grant applications are sought to develop:

(1) robust but sensitive biosensor devices (devices employing biological molecules or systems in the sensing elements), or critical technologies for them, that can be used for field-monitoring of environmental 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 the atmosphere or the terrestrial or marine ecosystems. Grant applications should 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 immunological linked detection systems, membrane lipids, or DNA/RNA probe technology with amplification and hybridization.

(2) enhanced sample purification methods/techniques for biomolecules which will minimize the required sample size and permit in-situ detection. Examples of purification processes currently used are centrifugation, precipitation, and agarose gel electrophoresis, depending on the intended test.

(3) new nucleic acid probes/primers for detecting specific environmental microorganisms. Probes may detect genes or the level of expression of the genes. Candidate probes/primers should state the environmental significance of the metabolic trait and relate the trait to DOE needs. In addition, the level of discrimination to be targeted (i.e., genera, species, or subspecies) must be rationalized.

Minor adaptations of readily available materials or hardware for such use will not be considered responsive to this subtopic.

d. Fiber Optic, Solid-State Chemical, and Silicon Sensors—Fiber optic sensors (classified as intensity-based,

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wavelength-based, or phase-based 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. The benefits of small-scale monitoring devices include simpler deployment in remote locations, potential cost advantages, and enhanced access to the monitoring site. Sensors and systems proposed must be able to detect geological, biological, chemical, or physical processes that transport, disperse, and transform energy-related materials in the atmosphere or the terrestrial or marine ecosystems.

Grant applications are sought to develop: (1) robust but sensitive fiber optic, solid-state chemical, or silicon micro-machined sensors or sensor arrays, or critical technologies for them, for field-monitoring of environmental processes or parameters (atmospheric, oceanographic, or terrestrial), or (2) integrated sensing and microprocessor/signal processing systems for autonomous or unattended measurement applications which utilize fiber optic, solid-state chemical, or silicon micro-machined sensors (either a single sensor or a suite of sensors). Innovative integration of components such as micro-machined pumps, valves, and micro-sensors into a complete sensor package will be considered responsive to this subtopic. However, minor adaptations of readily available materials or hardware for such use will not be considered responsive. In addition, grant applications must address the environmental significance of the parameter to be monitored by the proposed sensing devices.

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* See Section 7.1

PROGRAM AREA OVERVIEW - ENVIRONMENTAL MANAGEMENT

http://www.em.doe.gov

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The Environmental Management program seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities.

DOE's goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deploying technologies to address these goals. Radioactive contaminants are the prime concern in DOE waste management and environmental remediation activities, but hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

Reduction in cost of treatment and disposal of wastes and in environmental problems can be achieved by a number of approaches. These include reducing the volume of waste or waste streams directed toward disposal; altering the characteristics of the waste or waste streams to allow less expensive disposal; recycling materials used in treatment to reduce costs; or retrieving economically valuable materials from the wastes to offset costs of treatment and disposal. The following three topics seek grant applications which will employ these approaches and others to the treatment and disposal of radioactive and other hazardous wastes.

19. REMEDIATION OF SUBSURFACE CONTAMINANTS

Nearly all Department of Energy (DOE) facilities have landfills, buried waste areas, or burning grounds. These facilities contain a variety of contaminants (including organics, inorganics, and radioactive materials, as well as mixtures of these), often in the form of contaminant plumes. To control these contamination plumes, DOE's strategy is to first contain the contaminant source, then remediate the source, and finally, remediate the plume. This topic focuses on innovative methodologies to implement this strategy. **Grant applications are sought only in the following subtopics:**

a. Source Containment—Innovative materials are needed for containing concentrations of contaminated materials which would otherwise provide a long term (>100 years) source for the continuing contamination of soils and ground water beyond the source area. Current methods of containment of a contaminated zone include: caps (covered with overburden) installed above the zone, vertical barriers installed around the perimeter of the zone, floors placed below the zone, and angled barriers installed around the perimeter of the zone which also extend underneath the zone to serve as both a floor and a lateral barrier. Grant applications are sought for innovative materials that resist degradation from inorganics, organics, and radionuclides.

b. DNAPL Remediation—Dense Non-Aqueous Phase Liquid (DNAPL) plumes are a major environmental problem across the DOE complex and are also common problems associated with industrial sites. Grant applications are sought for innovative methods to remediate soils and

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groundwater contaminated with DNAPLs. Areas of interest include technologies capable of accurately delineating DNAPL plumes; technologies that enhance the extraction or removal of these contaminants; and technologies that are capable of destroying contaminants in place, e.g., by using reaction zones or reactive material. Of particular interest are minimally invasive technologies which will allow the DNAPL contaminants to be removed or destroyed without extensive excavation (which would result in increased environmental damage and worker exposure potential).

c. Metals and Radionuclides—While metals contamination is common in the private sector, radionuclide contamination is almost unique to DOE. Grant applications are sought for innovative methods for remediation of soils and ground water contaminated with metals and radionuclides. Secondary treatment technologies, for more complete remediation of removed groundwater or soils, are also of interest. For metal remediation, emphasis is placed on *in situ* technologies which immobilize the contaminants in place or which render the metal environmentally safe by altering its chemical state or availability.

Because many metal and radionuclide contaminants are valuable as resources, grant applications are also sought for technologies which would recover these contaminants for reuse or sale.

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5. Subsurface Contaminants Focus Area
   http://www.envet.org/scfa/index.html
6. Global Network of Environment and Technology
   http://www.gnet.org

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* See Section 7.1

20. TECHNOLOGIES FOR DECONTAMINATION AND DECOMMISSIONING

This topic focuses on a number of Department of Energy (DOE) facilities with particular decontamination and decommissioning challenges. In the United States, uranium is enriched in three gaseous diffusion plants, located at Oak Ridge, Tennessee, Portsmouth, Ohio, and Paducah, Kentucky, which contain large amounts of equipment (representing more than 750,000 tons of metal). In addition, about 50,000 tons of masonry (concrete, block, brick, etc.) are contained at the Oak Ridge site alone. The process equipment (including axial and centrifugal compressors, converters, control valves, and piping) has, by the nature of the process, been internally contaminated with radioactive materials. The major radiological contaminant is uranium and a minor amount of technetium. In addition to the known internal contamination, the external surfaces may be contaminated with radiological and/or hazardous materials (RCRA, TSCA) such as PCBs.

Mercury-contaminated process equipment can be found in lithium processing facilities at the DOE Y-12 Plant in Oak Ridge. Mercury is a highly toxic substance which, with excessive exposure, can lead to human and animal symptoms of heavy metal poisoning. Significant environmental damage

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can also potentially occur through air emissions and releases of mercury in soils and water systems. There is an estimated 7,000 tons of mercury-contaminated equipment at Y-12.

The decommissioning of the DOE Pantex Plant is another high priority for which high explosives are one of the primary contaminants of concern. The contamination is not only present in the bays and cells utilized for high explosive fabrication, but also in the facility piping and ventilation systems. Such contamination poses significant obstacles for characterization, decontamination, and remediation. Explosive facilities also exist at Los Alamos National Laboratory where sites utilized for weapons testing include firing ranges, tanks, disposal pits, landfills, old laboratory areas, septic tanks, and incinerators. Possible contaminants include radionuclides, high explosives, acids, heavy metals, organics, and petroleum products. Cleanup levels are either regulatory derived or determined by the application of DOE Order 5400.5 and the use of RESRAD and the ALARA process. Grant applications are sought only in the following subtopics:

a. Decontamination of Gaseous Diffusion Plants—Decontamination of equipment in gaseous diffusion plants has a number of technical challenges: (1) the complex geometries make cleaning difficult; (2) the combination of some mobile contaminants (such as technetium) and some porous metal forms (aluminum components and nickel barrier material) lead to contaminant migration into the matrix of the metal, making it more difficult to remove; (3) there are uncertainties about decontamination technical effectiveness, such as the degree to which certain technologies can remove technetium-99 (which is present from using recycled reactor feed). Various techniques (e.g., wiping, washing, blasting, chemical cleaning, scarification, vacuuming, nitric acid) have been used in decontaminating gaseous diffusion plants; however, their drawbacks include labor intensity, cost, and the generation of secondary waste.

Grant applications are sought to develop new or improved technologies to characterize, decontaminate, and dismantle the equipment. Proposed methods should take advantage of the repetitive nature of the equipment but should not become burdened by labor needs or secondary waste generation. In addition, cost savings should be provided over the current conventional methods, and worker exposure to radiation should be reduced. The goal is the decontamination of enough equipment and piping to allow for the free release of the metals on the open market.

Improved decontamination processes are also needed for contaminated concrete and painted surfaces. In many cases, the concrete surfaces have been covered with paint to fix the contaminants on the surface. Mobile shot scabblers have routinely been used for large surface areas, but this equipment is extremely time consuming and costly.

b. Dismantlement and Materials Disposition of Gaseous Diffusion Plants—Conventional dismantlement tools include manual/hydraulic cutting shears, high-pressure water jets, saws, grinders, shears, and plasma and acetylene torches. Improved processes are needed which will avoid volatilization of the contaminant during the cutting process. The cutting methods must also accomplish the cutting without spreading the contaminants to surrounding areas. Grant applications are sought for dismantlement tools that are versatile, easy to control, provide worker safety, and provide cost savings over the current conventional methods.

Grant applications are also sought to develop technology for the recycle/reuse of contaminated resources, such as process equipment, piping, and concrete. It is also recognized that the equipment in gaseous diffusion processes contains large quantities of valuable nickel, which could be recovered. Current baseline technologies include on-site storage, burial at disposal sites, and decontamination for free-release (for non-porous materials). However, these technologies present risks to both the environment and the worker, as well as regulatory compliance problems. Constraints include diminishing storage space and increasingly restrictive environmental regulations. On site storage requires continuous surveillance and maintenance; cross-country transportation of wastes is neither reasonable nor politically acceptable. The most desirable solution is to turn the radioactive scrap metals into products for controlled beneficial reuse.

c. Decommissioning of Lithium Processing Facilities—Grant applications are sought to develop an improved process for mercury decontamination at lithium processing facilities. Improvements over thermal desorption (roasting), currently used for small contamination problems,

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must be demonstrated. A method for inventorying the mercury contained in the equipment, and assuring that all of it is recovered, must be provided. Mercury air emissions requirements must be met during the decontamination process. Lastly, to minimize worker exposure, grant applications must address the issue of personal protective equipment and provide constant surveillance of mercury vapors.

d. Decontamination and Decommissioning of Facilities Containing High Explosives—Current baseline technologies include hot gas decontamination (circulation of hot gas throughout an existing building to volatilize explosives; the contaminated air stream then passes through a thermal oxidizer where the explosives in the air stream are destroyed), radical initiated decomposition (complete decomposition of nitroaromatic and nitramine explosives to volatile and non-toxic gases with hydroxyl radicals and the generation of carbon-based radicals), base initiated decomposition (rapid decomposition of high explosives to non-explosive and volatile and non-toxic products using sulphur derived reductants), water jet technologies (where high pressure water jets impact the surface media and remove contamination on surfaces), atmospheric plasma jet (where high explosive contaminants are oxidized with an atmospheric plasma jet using a high explosive/oxygen gas mixture and radio frequency power), and chemical extraction (in which a chemical is applied to extract high explosives from contaminated media). Grant applications are sought to develop improvements to these technologies, which would have lower cost, take less time, be applicable to more than one high explosive site, and provide increased worker/public health and safety. Both new technologies, as well as improved versions or combinations of the baseline technologies will be considered.

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21. EFFICIENT SEPARATIONS AND PROCESSING

Separation and processing technologies can remove radionuclides, hazardous materials, and chemicals from radioactive wastes, contaminated soils and groundwater, and waste streams resulting from the decommissioning and decontamination of facilities. Separation and processing technologies can also remove bulk inert materials from radioactive or hazardous waste streams, thereby reducing volumes or enabling more efficient subsequent separations and processing.

Grant applications should identify separations or processing technologies which are selective for specific contaminants of interest; produce low-volume secondary waste streams; reduce total systems cost and risk, and provide high loading capacities, high separation factors, and simplicity of operation. Technologies having commercial potential outside of the Department of Energy (DOE) are strongly encouraged, but all grant applications must target a specific DOE problem and provide sufficient detail about the

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proposed technology and the baseline technology (for that specific problem) so that a clear evaluation can be made. Of particular interest are technologies that offer application where no alternative is currently available, offer a rapid deployment to meet DOE needs, and extract economic values from waste streams. In all cases, flexibility is important; for example, a technology that addresses multiple contamination situations is preferable to one that addresses a single situation.

For applicants that do not have the facilities to perform research involving radioactive species, grant applications will be considered in which an innovative separation or processing technology is demonstrated with a nonradioactive simulant. The approach must, on further development, be applied to radioactive species. **Grant applications are sought only in the following subtopics:**

a. Aqueous Waste Streams—Grant applications are sought for separation or enabling processes to remove contaminants from dilute aqueous streams such as groundwater (either *in situ* or using pump and treat operations), streams arising from decontamination and decommissioning operations, and slightly acidic offgas scrubber solutions. Radionuclides and other materials under consideration include Resource Conservation and Recovery Act (RCRA) and heavy metals such as (thorium, mercury, chromium (III and VI), lead, cadmium, and copper; RCRA organics; transuranic elements (TRU) such as neptunium, plutonium, americium and curium; long lived soluble fission products such as technetium (99Tc) and iodine (129I); and activation products such as carbon (14C) and tritium (3H). Innovative separations or processing methods could include the addition of complexants to the feed to adjust the effective selectivity of a sorbent during loading, in which case the repercussions of introducing the complexant must be considered. Of particular interest are technologies that can perform highly selective calcium/strontium separations for groundwater treatment and methods for the removal of complexed technetium (in, for example, radioactive tank waste applications). Technologies applicable to concentrated aqueous waste streams (such as radioactive tank waste streams) will also be considered.

b. Solid Wastes—Solid wastes include sludges from defense reprocessing activities, solids such as metals and concrete from decontamination and decommissioning operations, excavated soils from environmental remediation activities, and fine solids and colloidal particulates in aqueous waste streams (solid/liquid separations). Highly radioactive sludges are typically metal oxides with large amounts of potentially soluble materials such as sodium or aluminum. Typically, the amount of waste that is radioactive is only on the order of 0.1 percent. Grant applications are sought for the direct removal of the radioactive materials (e.g., selective leaching of transuranics and strontium) or for the removal of the bulk constituents (aluminum, sodium) to leave a smaller volume of high level waste. Technologies to remove problem species are also sought, for example, the selective oxidation of chromium species to chromium (VI) without concurrent oxidation of transuranics or organics. Methods such as bulk leaching, selective leaching with dissolution, and extraction will be considered.

In addition, soils at DOE facilities contain a wide variety of radioactive, toxic, and heavy metal contaminants. Some of the most common are uranium, technetium, trichloroethylene, and polychlorinated biphenyls. Reagents that can assist in the electrokinetic decontamination of soils are also sought.

Lastly, grant applications are sought for high temperature and chemical methods to separate radionuclides and hazardous materials from calcined waste streams. Of particular interest are processes that separate species into concentrated product streams, that can withstand a radiolytic environment, that are economically viable, that can be scaled to processing rates of 2 to 30 gallons per minute, and that are simple to construct and operate.

c. Waste Streams from Decontamination and Decommissioning Operations—Waste streams arising from decontamination and decommissioning (D&D) operations are likely to be the largest volume streams in the DOE complex. Waste streams can be liquids (primarily aqueous), debris, solids, and sludges. The costs of treating these wastes can become the largest cost component of the whole D&D operation. If contamination can be removed while leaving the host matrix in place, then significant savings can be realized in operational costs.

Grant applications are sought to reduce the volume and costs of removing secondary wastes from D&D operations. These

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secondary wastes may be aqueous, solid, sludge, or debris. Technologies that operate so as to avoid the generation of mixed waste (by removal of either the RCRA or radioactive component to produce a non-mixed waste stream) are of particular interest.

Grant applications are also sought for the removal of contamination residues close to the surface of the host matrix (predominantly metal or concrete) during surface decontamination operations. Though a number of surface decontamination techniques exist, many are complicated by the generation of mixed waste or use of potentially hazardous components. Technologies or approaches that can overcome these problems are actively solicited.

Lastly, grant applications are sought to develop technologies for decontamination of tritium contaminated facilities and equipment. Facilities that have handled tritium (primarily as a gas, though the tritium may have undergone speciation over time to produce tritiated waste or tritiated organic compounds) present a significant problem to DOE.

d. Subsurface Contaminants—Subsurface contamination at DOE sites may include single or multiple species of radioactive or hazardous materials. Grant applications are sought for technologies that can: (1) enhance the removal of contaminants (particularly metals) by approaches such as electrokinetics, or (2) stabilize contaminants in place. Though *in situ* approaches are favored, pump and treat processes remain an option. In such cases, treatment of the secondary wastes may be complicated by the presence of fine solids and colloidal particulates, extremely dilute contaminants, or competing ions.

Also of interest are technologies for the economical removal of tritium in tritiated water. Though a number of technologies are currently available to separate tritiated water from normal water, the concentrations at which tritiated water occurs in groundwater contamination situations renders most of these technologies ineffective for economic reasons.

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PROGRAM AREA OVERVIEW - NUCLEAR PHYSICS

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

The Nuclear Physics program develops and supports basic research needed to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature. It is now 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, mainly pi mesons (pions). The research forefront in nuclear physics now requires incorporation of the quark substructure of the nucleon into the understanding of

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nuclear structure and in quark-antiquark pairs to form the mesons. Quarks, which are the most elemental building blocks of matter, are bound together in groups of three by the exchange of gluons to form the nucleons.

Attendant upon this core mission are responsibilities to enlarge and diversify the Nation's pool of technically trained talent and to support and maintain facilities for conducting nuclear physics research. The program works in close coordination with the Nuclear Physics program at the National Science Foundation (NSF), and jointly, with the NSF, charters the Nuclear Science Advisory Committee to assist in setting scientific priorities.

The SBIR topics which follow describe research opportunities in equipment, techniques, and facilities, needed to conduct nuclear physics experiments so that we can further our understanding of nuclear structure.

22. 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 with applicability to nuclear physics research clearly noted 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 photomultipliers 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 with applications to gaseous detectors; micro-channel plates; and 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 and efficient polarization-analyzing materials; and (6) 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.

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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 and long-term stability, 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 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 Relativistic Heavy Ion Collider and the Thomas Jefferson National Accelerator Facility. These data, continually produced at rates of 20 Mbyte/sec or more, result in the annual production of data sets on the order of 100 Terabytes. (The estimated computing power required to process these data is many hundreds of GigaFlops.) 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. All applications must show relevance to DOE's current Nuclear Physics program.

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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23. 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 significantly to overall accelerator technology and applications tailored to nuclear physics scientific research. Areas of interest include work conducted at the Relativistic Heavy Ion Collider with heavy ion energies up to 100 GeV/amu for each beam, superconducting accelerator devices such as the Thomas Jefferson National Accelerator Facility 4 GeV CW electron machine, as well as the development of devices and/or methods that would be useful in the generation of intense accelerated beams of radioactive isotopes related to the Radioactive Ion Beam Facility or with a future Advanced Radioactive Ion Beam Facility. Relevance of applications to nuclear physics must be explicitly described. **Grant applications are sought only in the following subtopics:**

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a. Materials and Components for Radio Frequency Device—Grant applications are sought for research and development leading to improved or advanced concept superconducting and room temperature materials or components for radio frequency (rf) devices used in particle accelerators. Areas of interest include: (1) peripheral components such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, and magnetostrictive cavity tuning mechanisms; (2) termination materials for use at 2 to 4 K, compatible with the ultra high vacuum and dust-free environment, and capable of absorbing microwaves efficiently from 2 to 90 GHz (>12 dB return loss, 2 to 4 GHz, S-band waveguide, length <12 cm); (3) methods to avoid inclusions in the superconducting material and contamination on the surface of the superconductor (which are very important for minimizing field emission, quenches due to localized heat sources, and excessive global heat dissipation); 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 Systems—Grant applications are sought for the design, fabrication, and operation of radio frequency structures and systems. Areas of interest include: (1) superconducting and conventional continuous wave structures for the pre-acceleration of radioactive beams, which can operate in the velocity regime between 0.001 and 0.01 times the velocity of light, for ions with charge-to-mass ratios between 1/30 and 1/240; (2) rf accelerating structures with large acceptances and that maintain good beam quality in both longitudinal and transverse phase spaces; (3) the economical fabrication of rf cavities with more than five cells while still providing 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 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 - such coupling systems should not contribute contamination to the cavity environment and should dissipate less than 10^{-4} of the transmitted power as heat load at 2 K with an overall voltage standing wave ratio of less than 1.1 (the operation of the rf transmission system should be free of multipacting and unaffected by the presence of radiation produced by field emission in the accelerating cavities).

Power requirements could be significantly reduced if the 5 kW, 1500 Mhz 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 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

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for nuclear physics research. Developments that offer generic solutions to problems in the initial choice of operational parameters and the optimization of selected beam parameters with automatic tuning are especially encouraged.

Grant applications are also 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 to 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 which form the technical basis of modern society.

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

Experimental research in HEP is primarily performed by university scientists using particle accelerators located at major laboratories in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago IL, the Stanford Linear Accelerator Center (SLAC) near San Francisco CA, and the Alternating Gradient Synchrotron (AGS) complex at Brookhaven National Laboratory (BNL) on Long Island, NY. 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 and the AGS also provide unique experimental capabilities.

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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 which follow include four accelerator-related topics and two detector-related topics.

24. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The Department of Energy (DOE) High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in the following areas: (1) new concepts for acceleration, (2) novel device and instrumentation development, (3) inexpensive electron sources, and (4) computer software that will contribute to overall advances in accelerator technology applicable to the High Energy Physics program. Relevance to applications in high energy physics must be explicitly described. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 23. 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 >10 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 (rf) amplifier tubes operating at wavelengths from 0.1 to 10 cm. Permanent magnets in these optical elements which are made 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 one J energy in 50

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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 four picoseconds in dual frequency (for example, near 1.05 micrometer and 1.06 micrometer) operation with a repetition rate of better than two per hour. Proposals 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 rf linac to a high level of precision (less than approximately one picosecond cycle-to-cycle jitter).

c. Inexpensive 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 and commercial or industrial spinoff applications. 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. Commercial or industrial applications using this technology may have other specifications.

Grant applications are also sought to develop 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 drive 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. The following areas of investigation are 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 quite 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 several microsecond pulses at about 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.

d. Computer Software—Grant applications are sought 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.

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25. RADIO FREQUENCY ACCELERATOR TECHNOLOGY FOR HIGH ENERGY ACCELERATORS AND COLLIDERS; AND FREE ELECTRON LASERS FOR ENERGY RESEARCH

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. For subtopics 'a', 'b', and 'c', relevance to applications in high

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energy physics must be explicitly described. Awards in subtopic 'd' will be sponsored by the Department's Office of Basic Energy Sciences to support the application of free electron lasers to research efforts in chemistry and materials science; the subject appears in this topic because of the close relationship between free electron laser technology and particle accelerator technology.

Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 23. 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 >10 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 0.25 to 25 cm.

b. Radio Frequency Power for Linear Accelerators—Grant applications are sought for new concepts, approaches, 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 rf power handling components which are not presently available, e.g., rf windows, couplers, mode transformers, rf loads, and high power rings capable of operating at high pulse powers (20 - 100 MW), high frequencies (11 - 100 GHz), and pulse lengths of several microseconds. Areas of interest include rf components such as mode converters from rectangular to circular waveguides, high-power rf windows, and high-power rf pulse compression methods for use in future linear colliders.

Also sought are 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 power, 2-10 msec (millisecond) pulse length, and 5-100 Hz repetition rate.

c. New Concepts for Pulsed Power Modulators— 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 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

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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 27.

d. Free Electron Lasers for Energy Applications—Grants are solicited for the development of advanced wigglers for high power free electron lasers. Superconducting designs which combine high field and a large gap-to-period ratio will be considered. Advanced taper designs will also be considered. Taper schemes should optimize the gain-efficiency product and should produce the largest possible ratio of extraction to exhaust energy spread. Wiggler wavelengths of 0.3 to ~2cm and full gaps of order 1cm are desired while producing K values approaching or exceeding one.

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26. ADVANCED CRYOGENIC, 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) advanced cryogenic, (2) high-field superconductor, (3) and superconducting magnet technologies. This topic addresses only those cryogenic, 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 selection. 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. Cryogenic Technology—Grant applications are sought to develop new and significantly improved cryogenic devices and systems for providing large-scale helium service in the temperature range 2 to 20 K. Areas of interest include the development of new or significantly improved heat exchangers and rotating machinery (turboexpanders, circulating pumps, and compressors).

b. 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 goal for the future is 15 to 20 Tesla. Applications must demonstrate such property improvements as higher critical-current densities, 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 also include methods to utilize high aspect ratio strands or tape geometries in particle accelerator applications. Materials of interest include: niobium-titanium, niobium-tantalum-titanium, the so called "A-15" compounds (e.g., niobium-tin and niobium-aluminum), and oxide (high temperature) superconductors. Regarding oxide superconductors, a minimum current density of 1200 A/mm^2 (not cm^2) in the superconductor itself and a minimum current density of 250 A/mm^2 over a total conductor cross section, at 12 Tesla minimum and 4.2 K, must be produced.

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.

c. 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 high-temperature, superconductor-based current leads for application to high-field accelerator magnets--requirements include current level at 5 KA or greater, stability, low heat leak, and good quench performance; and (3) alternative designs, to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets, that are more compatible with the more fragile A-15 and the oxide, high-field superconductors.

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

The Department of Energy (DOE) High Energy Physics program includes research and development (R&D) of technologies for a TeV-scale electron-positron linear collider that would use normal-conducting X-Band (11.4 G Hz) 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. Proposals 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) shall include certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

a. Direct Current (DC) and Pulsed Power Components—

DC power supplies: A "hot swappable" 5 kW (nominally 40 V, 125 A) power supply with 100,000 hours MTBF and efficiency > 90 percent. It is desired to remove and replace a supply without disturbing the supplied current. The design must provide small physical size and be cost effective. **Differential Current Transducer**: A current transducer with (i) low cost, (ii) minimum 2.5 inch diameter center hole for two conductors carrying up to 750 amps each, (iii) dynamic range ±100 mA accurate to 1 mA, and (iv) overload and failure indication. **Traveling Wave Tube (TWT) Cathode Pulser/Power Supply:** A highly-reliable cathode pulser and power supply to drive an X-band TWT. The pulser should deliver a 10 kV pulse to the heater/cathode element of a 1.2 μperv TWT. Rise and fall times should be < 1 μsec each and the 2 μsec flat-top should be within 0.2 percent ripple and droop. Low-cost and compact packaging are important. **Modulators:** Pulse modulators for klystron amplifiers must provide good efficiency, reliability, and maintainability, and be produced at low cost. Each modulator must support two klystrons and deliver a 500 kV pulse into the combined impedance of 1 kΩ at repetition rates up to 180 Hz. The rise and fall times of the voltage pulse must be below 300-400 ns and the output flat-top must be 1.5-1.8 μs. *Thus, grant applications are sought to develop:* **Power Supply for Dual Klystron Modulator:** A 100 kW power supply to charge a pulse forming network (PFN) of total capacity 0.2 μF to a maximum of 80 kV in < 500 μsec with electrical efficiency > 90 percent. The supply must be compact in size, highly reliable (MTBF > 50,000 hours), and cost-effective to manufacture and maintain. **High Power Switch:** A hydrogen thyratron or other type high-power switch capable of operating at 80 kV and switching up to 8,000 amps in < 50 ns. The switch should have MTBF > 50,000 hours and the total operating power should be minimized. Applications are also sought to investigate solid state devices to replace thyratrons. **Pulse Capacitors:** Capacitors for PFNs require series inductances < 50 nH with capacitance > 0.005 μF for 80 kV pulses. The PFN must be charged to 80 kV in 500 μsec and fully discharged during the 1.5 μsec output

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pulse. Circuits must withstand partial voltage reversal during non-standard conditions. The PFN must be compact and reliable (MTBF > 100,000 hours). **Pulse Forming Line**: Ferrite loaded, ceramic dielectric, or coaxial transmission lines in tubular or strip configurations. Lines must be compact and configured as 4 - 5 Ω impedances. The high-voltage high-current connections must be considered. **Pulse Transformers:** A transformer (ratio 1:14) to convert 35 kV/7,500 amp PFN pulses to 500 kV/530 amp pulses (with 1.5 μsec flat-top with rise time < 300-400 ns and droop and ripple < 2 percent) that drive two 0.75 μperv klystron cathodes in parallel. The transformer must operate in 40 kV breakdown transformer oil, be compact, efficient, and cost-effective to manufacture.

b. Microwave Power Technologies—Three components of the klystron amplifiers that power the accelerator are major cost drivers: the electron gun, collector, and rf window. Grant applications are sought for lower-cost, higher-reliability, and longer-life components in the following areas: **Electron gun:** (i) a less costly high-voltage (500 kV for 2 μs pulse) vacuum seal, (ii) high-current (10 A/cm^2), long-life (MTBF >/= 50,000 hours) cathodes and heater packages, (iii) packaging to minimize fixturing and assembly labor. **Collector:** Low-cost fabrication and innovative cooling designs for a 140 MW peak power, 20 kW average power electron beam collector. **RF Window:** Low-cost rf window designs which will reliably pass 75 MW of peak rf power, 11 kW of average rf power for > 50,000 hours. **Materials Processes for Mass Production of Ultra-High Vacuum (UHV) Components:** Grant applications are sought to develop or advance net shape or near net shape manufacturing for high-conductivity (100 percent dense) oxygen-free (ASTM F.68, Metallographic Class I) copper components used in ultra high-vacuum (equilibrium vapor pressure > 1 x 10^{-9} Torr @ 300°C) high-power microwave applications. Mechanical tolerances from a few microns to 50-100 microns and surface finishes of 10 nanometers must be achieved for a few of these parts. Development must yield significant cost reduction over current numerical controlled machining methods. Other materials (stainless steel, aluminum, copper alloys) are of interest if applicable to a high-volume linear collider component.

c. Auxiliary Systems—Signature Processing and Identification: Grant applications are sought to develop techniques to measure and characterize ambient vibration signatures from near and far, point and line, acoustic sources. Frequencies up to several hundred Hertz are of primary interest. **Signature Reduction:** Grant applications are sought to develop techniques to control vibration in central and distributed auxiliary systems. Static and dynamic techniques can be considered, and frequencies up to several hundred Hertz are of primary interest. Cost and reliability are important. **HVAC:** Grant applications are sought to develop techniques to cool enclosed racks of power electronics. Nominal operation is 25°C for heat loads of 3-5 kW per enclosure. Total heat load for the combined enclosure system is 35 MW distributed in clusters over 30 kilometers. Cost and reliability are important.

d. Controls and Instrumentation—The linear collider control and monitoring electronics are distributed over 30 kilometers. Low cost with very high reliability and maintainability are critical issues. Grant applications are sought to develop or advance technologies in the following areas: **X-band Phase Shifter:** New or optimized X-Band microwave phase-agile phase shifters. Phase must be programmable to all angles with < 0.3 dB amplitude variation and a phase shift must settle in < 3 nanoseconds. Operation is at 100 milliwatts with < 3 dB insertion loss and VSWR < 1.05. **Beam Position Monitors (BPMs):** The BPM electronics digitize amplitudes of signals induced by bursts (180 PPS) of 100 bunches of 10^{10} electrons (2.8 ns bunch spacing). This sampling rate, reliability, and economy suggest integration on a chip. A grant application should consider packaging, cabling, control, power, cooling, timing, cost, and reliability. Some radiation exposure to electronics is possible. **Microwave BPMs:** Electronics for microwave BPMs that sense amplitude and phase in a 15 MHz band at 14-16 GHz. Resolution requires -22 dBm noise power referred to the input. Peak powers can exceed 10 kW. A down-conversion must occur near the source; IF and baseband processing could also be done locally. System cost, reliability, packaging, and interfaces must be considered. Radiation tolerance will affect location of components. **High-Bandwidth Acquisition and Control:** Extended communications links and inexpensive processors to implement feedback with bandwidth at 0.1 to 1 kHz. Architectures should keep real-time processing near data

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ports and minimize real-time latency between processing nodes. Goals include good noise immunity, maximum buffer lengths, and high reliability and maintainability. **Vacuum Control:** Modular controls that work for either a vacuum pump or gauge. Millisecond response, range from 10^{-3} amps to 10^{-11} amps on a single log scale, and interlock outputs are required. Also of interest is a programmable controller to accept several interlock signals and provide power to close a vacuum valve. Cost and reliability are important. **Ion Chamber Power:** A power supply for zero-gain gaseous ion chambers that require high-voltage (300-400 V) with exceedingly good isolation from output to ground. Cost and reliability are important. **Stepping-Motor Control and Read back:** Distributed systems for precision stepping-motor drive and control. Remote front-end electronics must be radiation tolerant. Cost and reliability are important. Duty factors are low, so pulsed power and local board-mounted converters should be considered. **Control and Monitoring Links and Networks:** Investigation of tradeoffs between copper cable and medium bandwidth serial links to limited numbers of front-end devices. The technical and economic feasibility of fiber optic and copper links should be investigated and the top-end architecture studied for cost-performance. Remote front-end electronics must be radiation tolerant. **Network Protocols and Serial Data Acquisition and Control:** Protocols for real-time serial data collection with high reliability, timing precision and synchronization, and immunity from systematic errors. Consideration should be given to server or concentrator architectures. Issues include hardware options, availability of commercial software, and support for high-level protocols. **Personnel Safety and Monitoring:** Personnel safety systems in accelerators are function-critical and require: (i) redundancy and fail-safe implementation of all features, (ii) serial fiber or copper links from single entry points, (iii) firmware reconfigurability, (iv) modular architecture, (v) high reliability, (vi) radiation tolerance, (vii) optical or inductance interrupt switches, (viii) high-security card-reader key technology, and (ix) combined data, audio, and video to remote monitoring and control. **Pulsed Power for Instrumentation and Control:** Custom integrated circuits with pulsed power (180 PPS) for compact front-end electronics. It is desired to reduce the total power of a channel (typically 10 W steady state) to perhaps 1 W average. On-board DC-DC and AC-DC converters should be considered. Reliability and cost are of extreme importance for these applications. Remote front-end electronics must be radiation tolerant.

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* See Section 7.1

28. 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

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and computational technologies for the recording, processing, and analysis of experimental data, as well as for the monitoring and control of accelerator systems and devices is desired. Areas of present interest are event triggering, data acquisition, and data analysis systems and components used in high energy physics experiments and particle accelerators. **Grant applications must clearly and specifically indicate their particular relevance to present or future high energy physics programmatic activities.**

Although particle physics detector instrumentation and data processing equipment development and construction are usually centered in large, collaborative efforts at major national particle accelerator centers, there are many developmental endeavors in collaborative or stand-alone efforts where small businesses can make creative and innovative contributions to the further development of 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. Directories of appropriate researchers are available by institution at http://www.hep.net/sites/directories.html on the World Wide Web. 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-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 Cherenkov 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., CAMAC, 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., CAMAC, FASTBUS, or VMEbus).

Instrumentation Modules--Much of the electronics instrumentation in use in high energy physics is packaged in one of the international module interconnection standards (e.g., CAMAC, 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. Special Computer Systems and Peripherals

—Grant applications are sought for innovative software and hardware for applications in high energy physics experiments, data processing, accelerator control systems, and theoretical computations, including, for example, distributed microprocessor systems, pattern-recognition systems, database management systems, code development systems, emulators for high-speed computation, large scale parallel processors for large-scale simulation, and cost-effective, multiple-access, large-memory systems. Grant applications are also sought for hardware for local and wide area computer-to-computer networks, network switching devices, network monitoring and control

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instrumentation, cost-effective alternatives to magnetic tape or disk on-line storage, new approaches to very long-time or large-scale on-line data storage (e.g., optical disk), smart terminals, scientific work stations, and enhancements to CAD-CAM (computer-assisted design and manufacture) systems and devices.

c. Computer Software—Grant applications are sought for the production of computer software to meet identified computing problems. Areas of interest include: (1) computer network management, interconnection, and control; (2) transition to ISO network protocols; (3) CAD-CAM conversion between dissimilar systems; (4) systems for the management of very large databases of the type created in connection with the operation of large detectors; (5) general purpose software for controlling and interfacing with large electronic systems; and (6) software for the control of large multiprocessor systems. Grant applications are also sought for software for controlling, data recording, and/or data analysis for a major high energy physics detector system, or for an approach or system that will allow the control, data recording, and/or data analysis software for a large detector to be specified and produced commercially in whole or in part.

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.

d. Novel Data Handling Techniques and Systems for Particle Detectors—Grant applications are sought for innovative approaches to data handling for existing or anticipated experimental techniques and devices that result in more cost-effective or less complex systems for digitizing, handling, or recording detector outputs.

Grant applications are also sought for improved solutions to the specialized local communications problems encountered internal to large modern particle detectors. Particular areas of interest include the need for ultra-speed highly parallel systems to connect detector device output signals to the external electronic processing site. Grant applications are also sought for improved solutions to the specialized local communication problems encountered in connection with accelerator control systems.

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29. HIGH ENERGY PHYSICS DETECTORS

The Department of Energy (DOE) supports research and development in a wide range of technologies essential to experiments in high energy physics and to the accelerators at DOE high energy accelerator laboratories. The development of advanced technologies for particle detection and identification to be used 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 centered in major national particle accelerator centers, there are many developmental endeavors, especially in collaborative efforts, where small businesses can make creative and innovative contributions to the further development of 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. Directories of appropriate researchers are available at http://www.hep.net/sites/directories.html on the World Wide Web. 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. Particle Detection and Identification Devices—Grant applications are sought on 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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PROGRAM AREA OVERVIEW - 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 comprise 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. In addition, the program is identifying and exploring innovative approaches to fusion power that may lead to more economical power plants. It is felt that small businesses, by performing research within the following technical topics, can make significant contributions to these efforts.

30. FUSION PLASMA SCIENCE AND TECHNOLOGY

The Fusion Energy Sciences program seeks to improve the performance of high temperature plasma and expand the scientific understanding of plasma behavior. This necessarily involves the development and implementation of advanced technologies, both for magnetic and inertial fusion energy. It is also expected that concepts developed as part of the fusion research program will also have application to industries in the private sector.

The program currently supports several fusion experiments that have many common needs and problems. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts in plasma heating and fueling; diagnostic instrumentation for measuring plasma parameters; plasma density and impurity control, including improved computer capabilities for data analysis; and novel approaches for inertial fusion energy target drivers, namely, gas and solid-state laser drivers.

Grant applications pertaining to cold fusion will be declined, as will those pertaining to other fusion energy concepts not based specifically on magnetic or inertial confinement of plasmas for the purposes of producing energy/electricity for non-defense purposes. Also, grant applications which are essentially equivalent to applications submitted in response to the 1998 Small Business Technology Transfer (STTR) program solicitation (DOE/ER-0709) will not be re-reviewed. Grant applications are sought only in the following subtopics:

a. Plasma Heating and Fueling—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 and continuous operation. Grant applications are sought for the development of components related to generation, transmission and launching of electromagnetic waves in the above frequency range. These should withstand the harsh environment of the fusion research devices. Components of interest include: (1) antenna systems, (2) tuning and matching components, (3) mode converters, windows, output couplers, loads, diagnostics to evaluate the performance of such components, (4) improved power-supplies to replace heretofore used conventional transformer-rectifier systems, and (5) energy extraction systems from spent electron beams.

Grant applications are also sought for improved deuterium or tritium pellet injectors used for plasma fueling in magnetic fusion experiments, as well as for vacuum system components used to remove undesired particles.

b. Plasma Diagnostics—In fusion energy experiments, measurements are needed for major parameters such as plasma density, electron and ion temperature, plasma current and plasma current density, plasma position and shape, plasma impurity density, magnetic field strength, ambipolar potentials, and radiation from the plasma. Real time measurements of some plasma parameters will be needed for the control of long-pulse plasmas. In addition, methods are desired for examining the edge plasma region. Measurement of the properties of auxiliary plasma heating techniques and non-inductive current drive are of particular interest. Diagnostics suitable for experimental devices using relatively low magnetic fields and new innovative concepts are also desirable. Measurements require both good spatial and temporal resolution. Both absolute values and small relative differences in those values in space and time must be measured. Grant applications are sought to develop techniques for measuring these parameters.

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For plasma particles, grant applications are sought for systems to: (1) detect and characterize particles including ions, electrons, neutrons, and photons; confined and escaping charged fusion products of deuterium-deuterium and deuterium-tritium fusion reactions; and (2) determine the energy spectra, spatial distribution, and time evolution of thermalized plasma particles, including the charge state of the impurities. Areas of interest include improved accuracy and resolution compared to existing systems (e.g., increasing the signal-to-noise ratio in instrumentation or extending the range over which measurements can be made); sources and calibration techniques in the microwave and far infrared regions leading to improved electron cyclotron emission, scattering, reflectometry, and interferometry methods; infrared surface temperature measurement techniques for fast time response and magnetic field compatibility; calibration techniques for neutron measurement systems with a very wide dynamic range; and radiation resistance from the burning plasmas, allowing the system to function in the high vacuum and temperature environments.

c. Data Analysis and Plasma Control—Data obtained from diagnostic instrumentation will increasingly be used for real time control of the plasma. Grant applications are sought to develop computer algorithms for the real time control of plasmas by applying recent developments in control theory; hardware, including array processors and massively parallel computers; and software, including modern languages, expert systems, and neural network algorithms. The computer algorithms should be developed in conjunction with these techniques and should be based on the best available models of plasma behavior, address multiple time and spatial scales, and be validated against experimental data.

d. Laser Drivers for Inertial Fusion Energy—The Department of Energy supports research and development in heavy ion accelerators for application as drivers for inertial fusion energy. This subtopic focuses on new concepts to advance both solid-state laser drivers and gas laser drivers.

For solid-state laser drivers, grant applications are sought to identify and produce high-power laser gain media which meet the following requirements: (1) storage lifetimes greater than 1 millisecond, (2) extraction cross-sections greater than $3x10^{-20}$ cm^2, (3) extraction efficiency greater than 50 percent, (4) emission wavelengths which are less than 1 micron and compatible with efficient diode laser pumps, (5) capability to operate under instantaneous optical fluxes of 10 Joule/cm^2 in 3 nanoseconds at 10 Hz with gas-flow surface cooling, (6) capability of economical production in slabs greater than 10 cm x 15 cm in area, and (7) favorable optical and thermomechanical properties. One possible laser medium might utilize Yb:S-FAP laser crystals (i.e., S-FAP = Sr5(PO4)3F doped with ytterbium) pumped at 900 nm with laser diode arrays. For this medium, appropriate Yb:S-FAP laser crystals could be fabricated into a slab configuration, faced-pumped by the diode arrays, extracted at 1.047 microns in the propagation direction, and cooled with a flow of helium in millimeter-size channels. Such a diode-pumped solid-state laser has the potential of meeting the efficiency, beam-quality [not a part of this announcement], and scalability goals for ultimately achieving laser driven inertial fusion energy.

For gas laser driver technology, grant applications are sought to improve electron-beam emitters which would be used for pumping large-volume excimer (KrF) lasers. The emitter must be capable of: (1) operating in an applied magnetic field which is 1.5 to 2.0 times the self field of the electron beam, (2) 5-10 Hz repetition rates for at least one million discharges before maintenance [based on technology with potential to scale to 200 million discharges], (3) one percent shot repeatability at electron current density of at least 20 A/cm2, (4) operating at an applied voltage of 700 keV for at least 60 nanoseconds at constant impedance, and (5) being spatially uniform to within 10 percent over an area of 10 cm x 80 cm.

Relevance to applications in laser drivers for inertial fusion energy research must be explicitly described. Grant applications that are more appropriate to the inertial confinement fusion program of the Office of Defense Programs will be declined.

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* See Section 7.1

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31. FUSION MATERIALS AND COMPONENTS

Practical applications of magnetic fusion energy in the next century will require the development of structural, high heat flux and plasma facing materials; insulating coatings; superconducting magnets and materials; and components that can withstand the expected radiation, coolant, vacuum, temperature, and magnetic field environments. These materials and components are required to assure the safe, reliable, economic, and environmentally attractive operation of fusion energy systems. The long-range technical problems posed by these challenges create many research opportunities. Excluded from this topic is research pertaining to cold fusion, inertial confinement fusion, and other fusion energy concepts that are not based specifically

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on the magnetic confinement of plasmas. **Grant applications are sought only in the following subtopics:**

a. Structural Materials and Insulating Coatings—Grant applications are sought for research that will lead to the relaxation of operating limits for: (1) vanadium alloy structural materials, (2) silicon carbide/silicon carbide (SiC/SiC) structural composites, and (3) electrically insulating coatings to reduce magnetohydrodynamic (MHD) effects in vanadium alloy/liquid lithium systems. Specific topics of interest include, but are not limited to the following:

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 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.

b. High Heat Flux and Plasma Facing Materials—Plasma facing materials and components must survive high heat fluxes, plasma-induced erosion, and neutron damage expected in fusion energy systems. Surface heating conditions of interest include long pulse heat fluxes for first wall surfaces (0.1 to 1 MW/m^2), long pulse heat fluxes on divertor components (5 to 20 MW/m^2), and short pulse (about one thousandth of a second) heat fluxes on surfaces subjected to plasma disruptions (10 to 500 MW/m^2). Grant applications are sought for: (1) radiation resistant, high thermal conductivity, low activation materials and concepts to control erosion and deposition for limiters, divertors, wall armor, and liners; (2) heat dissipating materials and concepts; (3) non-silver joining techniques for graphites, carbon/carbon composites, tungsten, and beryllium; (4) compliant or functionally-graded interlayers with high thermal conductivity; (5) transpiration-cooled armor concepts; (6) techniques to enhance heat transfer and critical heat flux limits for water or gas-cooling; (7) radiation-resistant copper alloys with superior strength, thermal conductivity, fracture toughness, and fatigue properties; (8) in-situ inspection and repair techniques for damaged armor; (9) advanced fabrication techniques; (10) methods for in-situ removal of co-deposited tritium layers; (11) non-destructive evaluation techniques for armor joints and critical heat flux monitoring; and (12) liquid metal limiters, divertors, or cooling concepts.

c. Superconducting Magnets and Materials—This subtopic addresses the design and development of new or advanced superconducting magnet concepts 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 attractive 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).

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PROGRAM AREA OVERVIEW - NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

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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 about 22 percent of 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 plants 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 in four general program areas. In the Energy Resource area, activities include the development and demonstration of technologies that address critical issues associated with the continued safe operation of nuclear power plants, research and development to minimize spent fuel, and the management and sale of excess DOE-owned uranium. NE Science activities include the production of radioisotope thermoelectric generators and heaters for deep space missions, development of isotope technologies, and operation of research and test reactors. Environmental Quality activities include management of depleted uranium hexafluoride stored in cylinders at DOE sites and assessment of disposal options, deactivation of nuclear facilities, and development of advanced waste treatment technologies. Activities in the National Security area include providing power and propulsion systems for the Department of Defense, eliminating the production of weapons-grade plutonium in the former Soviet Union, converting weapons-grade uranium from dismantled Russian nuclear warheads to commercial-grade, and improving international nuclear safety by enhancing the design and safety of Soviet-designed plants.

NE's SBIR activities for this solicitation will focus on: (1) advanced technologies for civilian nuclear power plants, in order to maintain existing U.S. nuclear power plants as reliable, efficient sources of energy well into the next century, and (2) space power systems, to continue the Department's support for the Nation's space program by providing radioisotope power systems for use in space (for example, the instruments on the Cassini spacecraft, launched in October, 1997, on a mission to Saturn, will be powered by radioisotope thermoelectric generators built by the Department of Energy).

32. ADVANCED TECHNOLOGIES FOR COMMERCIAL NUCLEAR POWER PLANTS AND SPACE POWER SYSTEMS

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. Many of these existing plants have served the country well and reliably for decades, and can continue to operate safely and aged-related degradation of key reactor components after extended reactor operation, are better understood and properly managed. Innovative, technology-based research and development is needed to enhance commercial light water reactor (CLWR) technologies and techniques to: (1) locate operations-related defects in reactor pressure vessels (RPVs) and in steam generator tubing, and measure the embrittlement of RPV weld and plate materials using advanced nondestructive examination methods, (2) model, predict, and mitigate stress corrosion cracking in affected reactor system materials, and (3) characterize the condition

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of and predict the aging behavior of electrical cable jacket and insulation materials.

The Department of Energy also conducts research and development for radioisotope power system technologies in support of the Nation's space program. These systems are needed for deep space and planetary surface exploration missions where solar cells or batteries are not practical. Current applications require high efficiency, low to moderate power, light weight radioisotope power systems, and advanced heat source designs with space system compatibility. **Grant applications are sought only in the following subtopics:**

a. Advanced Nondestructive Examination (NDE) Methods for Reactor Pressure Vessels (RPVs) and Steam Generator (SG) Tubing—Materials in key reactor components such as RPVs and SG tubing can be damaged by the long-term operational effects of temperatures, stresses, radiation, and water coolants which are part of their operating environment. To assure safety, it is necessary to predict and measure the extent of this material damage and to determine its effect on the ability of these reactor components to perform as intended. Development of improved technologies and techniques that accurately characterize, measure, and predict the effects of this degradation on overall component performance is needed to assure long-term, safe reactor operations in a cost-effective manner. Current methodologies to characterize RPV integrity include monitoring mechanical property changes of materials susceptible to irradiation embrittlement via destructive testing of surveillance specimens and inservice inspection to verify the absence of service-induced defects in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI. SG tubing is inspected in accordance with the plant technical specifications.

Grant applications are sought to develop any or all of the following: (1) advanced *in situ* NDE methods that can correlate NDE measurements to mechanical properties (Charpy impact, tensile, fracture toughness) of RPV shell materials subjected to irradiation embrittlement, (2) NDE techniques for early detection, characterizing, and sizing of deleterious indications in steam generator tubing, and (3) *in situ* NDE methods that provide improved basis for determining the flaw-size dependent probability of detection and the sizing accuracy of existing NDE techniques. Innovative NDE techniques and methods for direct property measurement of RPV neutron embrittlement and for improved SG tube inspection and flaw analyses are of primary interest.

b. Stress Corrosion Cracking Modeling, Early Detection, and Mitigation Technologies—Stress corrosion cracking (SCC) of austenitic stainless steels has been observed in boiling water reactor (BWR) internal components. Also, irradiation assisted stress corrosion cracking (IASCC) is predicted to begin occurring in pressurized water reactor (PWR) internals at older plants as neutron fluence approaches the expected threshold for IASCC. At present, no mitigation method has been demonstrated to be fully effective for reactor internals. Most cracks are detected by visual examination rather than volumetric examination. Likewise, crack growth models that accurately predict SCC and IASCC of even simple structures do not exist. Success in any of these areas is expected to foster development of more effective maintenance programs which will minimize the need for costly replacement of reactor internals to ensure safety. A multi-faceted approach is required to manage reactor internals material behavior by developing: (1) technologies to alter the environment and mitigate degradation - multiple approaches to altering the environment are being considered (e.g., enhanced hydrogen water chemistry, noble metal chemical injection, zirconium oxide deposition), (2) examination methods to find incipient defects before cracking occurs, despite the complex geometry of most internals structures which makes it very difficult to perform volumetric examinations, and (3) crack growth prediction methodologies that fully incorporate environmental conditions and allow for component-specific considerations.

Grant applications are sought for the above CLWR applications to develop any or all of the following: (1) advanced SCC or IASCC mitigation technologies, especially approaches that improve the operating environment inside the reactor without degrading the environment in other areas, (2) NDE techniques for early detection of SCC or IASCC in reactor internals, and (3) SCC or IASCC modeling techniques to better predict reactor internals material behavior.

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c. Advanced Characterization Techniques and Modeling Methods to Predict Aging Behavior of Electrical Cable Jacket and Insulation Materials—Nuclear plant electrical cables are subject to various types of environmental aging, predominantly thermal and irradiation aging. Cables in critical applications are required to function during and after an accident. Since additional aging will occur during and after an accident, cables must have sufficient margin prior to a postulated accident. The functional performance of a safety circuit may be lost if jacket integrity is compromised or insulation dielectric strength is inadequate.

Grant applications are sought for technologies that provide advanced techniques suitable for *in situ* testing of a cable to: (1) characterize cable jacket and insulation material condition, (2) predict the remaining life of a cable based on science-based aging models, and (3) assess the ability of a cable to perform its safety function(s) during design basis events. Nondestructive techniques capable of characterizing the condition/performance of an entire cable run are of primary interest; techniques that require small samples from the ends of a cable or very localized samples are also of interest. For condition monitoring techniques that require samples, methods for obtaining samples without compromising cable qualification are required.

d. Radioisotope Power Systems—NASA's plans for future space and planetary surface missions call for small size spacecraft, landers, and robotic explorers. The power requirements for these future missions cannot be met by the current (nominal 300 watt electrical) General Purpose Heat Source - Radioisotope Thermoelectric Generator (GPHS-RTG) (see references 20 and 21). Future mission requirements must be met by new technology Radioisotope Power Systems (RPS). Grant applications are sought for new RPS energy conversion concepts in three ranges of electrical power output: 30 to 150 milliwatts, 5 to 20 watts, and 100 to 200 watts. Such new energy conversion concepts could include, for example, radioisotope excitation of fluorescent material matched to a photovoltaic cell. Developmental efforts should seek to maximize conversion efficiency and specific power. Other desirable RPS attributes include long life (15 year missions), and the ability to withstand launch and space environments. Consideration must also be given to power degradation mechanisms and kinetics and nuclear safety issues.

For electrical power systems in the 5 to 20 watt and 100 to 200 watt ranges, systems offering 28 volts DC at efficiencies of at least 20 percent, are being sought. Areas of interest include novel RPS electrical system designs employing Alkali Metal Thermoelectric Converter (AMTEC), Stirling include novel RPS electrical system designs employing Alkali Metal Thermoelectric Converter (AMTEC), Stirling Linear Alternator, or advanced high efficiency thermoelectric conversion technologies (see references 20 and 21). Development of life and/or efficiency enhancing subsystems are also of interest. Where possible, the General Purpose Heat Source (see reference 22) or a derivative of this module should be utilized, while adhering to the thermal constraints for this type heat source.

For the milliwatt power range, an output of approximately 15 volts DC, at an efficiency of at least 6 percent, is being sought. Areas of interest include milliwatt radioisotope power systems employing alpha or beta battery, AMTEC, thermoelectric, or other novel power conversion technologies.

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PROGRAM AREA OVERVIEW - ENERGY EFFICIENCY AND RENEWABLE ENERGY

http://www.eren.doe.gov

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

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

33. SMALL WIND TURBINE APPLICATIONS

In situations where reliable electric service is not readily available, small wind turbine systems can serve as a viable source of electric power for servicing an isolated grid or village power system, or as a dedicated power source for particular applications. In order to use wind energy for powering applications such as ice making, water desalination, water purification, or water pumping, appropriate technologies are required to ensure cost effectiveness, reliability, and optimum use of available wind energy. The applications for these technologies are a significant near-term market opportunity for U.S. industry in remote locations in both the United States and in developing countries. In many instances, these wind systems may compete, or may be used in conjunction with diesel or PV systems as the power source for the applications.

The Department of Energy is looking for practical (functional, robust, and economical) designs to best adapt

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wind turbine systems to serve these applications. An important component of a system design is the interface with the end user, accounting for diurnal and seasonal usage patterns, resource availability, power quality, and other considerations. Optimized dispatch of the energy source and cost effective design of the inverter-battery system (where applicable) are also important for these systems.

a. Ice Making Systems Designed to Operate with Wind Power—Ice making is an important application for power systems, especially in remote fishing villages. In such villages, ice is crucially important to the livelihood of the fishermen to preserve their catch until it can be shipped to market. Ice making is very well suited for wind systems since making ice is a form of energy storage which complements the intermittence of the wind resource. Also, ice making is a very productive supplementary load application for when there is excess wind resource, and where the primary product is electricity for general use.

In 1995 and 1996, researchers at the National Renewable Energy Laboratory (NREL) used a 75-kW dynamometer at the National Wind Technology Center's Hybrid Power Test Bed to evaluate whether a single wind turbine could run a commercial vapor compression cycle icemaker at variable speeds by using the variable frequency and voltage power directly from the wind turbine without any batteries or inverters in the system (reference 6). Tests showed that commercial ice makers need to be redesigned for this application. Therefore, grant applications are sought to develop design modifications for an ice making system which uses power directly from a variable-speed wind turbine. Possible approaches include using a variable speed compressor for the ice maker or designing equipment which is more adaptable to variable speed operation. Focused efforts that lead to the availability of products for reliable, cost-effective wind-powered ice making are needed.

b. Wind Powered Water Desalination—Water desalination is an extremely important need in many off grid coastal areas. Pilot projects have been implemented using wind powered AC inverter-battery systems to power reverse osmosis (RO) systems for water desalination, e.g., the Costa de Cocos project in Mexico (reference 3). However, these systems are expensive. Not only is the energy requirement of the RO system for water desalination high (i.e., the energy usage per liter water desalted), but the costs for the batteries and the inverter are also high because of the high-energy requirements. Grant applications are sought to develop a moderate-cost, robust, wind powered water desalination system, using commercially available water desalination technology (references 10, 13). One possible candidate would utilize vapor compression, which may result in a lower kW/liter requirement for water desalination, and hence be more cost-effective than the wind powered RO system (reference 12).

c. Water Purification—Water purification is closely related to water desalination. For most water desalination systems, water purification is included in the system design. In other systems where water is available but is not potable, a system for water purification is essential. Grant applications are sought to develop cost-effective systems for wind-powered water purification. One possible approach is to develop an optimization controller for wind-powered electrodialysis to supplement NREL's proposed demonstration (with the Bureau of Reclamation) of a wind powered electrodialysis unit for water purification of brackish water (references 8). Other approaches include directly coupled systems with no batteries, and innovative filtration or membrane separation processes.

d. Wind Powered Water Pumping System Controller Development—In wind-powered electric water pumping systems, the controller, which connects and disconnects the wind system to the pump, based on turbine speed, is often the weak link in the system. A common problem has been that the battery powering the charge controller would lose its charge, and hence the system would not function. Although improvements have been made in some recent systems, grant applications are sought to develop further improvements in the design and robustness of these controllers (references 2,11).

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34. HYBRID ELECTRIC VEHICLE TECHNOLOGY

In support of the Partnership for a New Generation of Vehicles (PNGV), new technology needs have been identified in connection with electric motors, electric systems, and engine combustion systems for future highway

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vehicles. These technologies could reduce the drive train cost and weight and improve the energy management, emissions, and control of electric and hybrid electric vehicles. This topic deals with reductions in the cost and weight of electric motors, advanced energy conversion technologies and sensor integration and architecture to increase the overall power efficiency, and improvement in performance and driving range with a reduction of start-up emissions. Grant applications are sought only in the following subtopics:

a. Improved Electric Motors for Hybrid Electric Vehicle Transportation Systems—The alternating current (AC) induction motor is a promising motor type to provide high electric propulsion efficiency over a wide power and speed range. Improvements in the cost and power density of the induction motor are needed to meet PNGV goals. For a reference 100 Kw motor, these goals are $4/Kw and 2 Kw/kg, respectively. To assist in meeting PNGV goals, grant applications are solicited to develop advanced AC induction motor technology for electric and hybrid electric power trains. For example, motors operating in high torque ranges may require innovative cooling techniques. Also, because a low part count will provide a lower cost motor, innovative ways to reduce motor parts counts are of interest. Grant applications should attempt to quantify the projected reduction in induction motor cost and weight, and show how the technologies could be applied to large volume manufacturing. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

b. Advanced Fuel Injection Concepts for Diesel Engines—In diesel engines, the fuel-injection system is responsible for complying with the engine's fuel-metering requirements. In current designs, components on the low-pressure side of the injection system include the fuel tank, fuel filter, fuel supply pump, overflow valve, and fuel supply lines. The fuel pressure required for injection is generated on the high-pressure side of the system, where the fuel is pumped through the delivery valve, high-pressure injector lines, and nozzle-holder assembly on its way to the injection nozzle. However, these current designs fail to provide a homogeneous mixture in the period following start-up, when the engine is cold or the system is not up to pressure. It is during this period that most pollutants are released. Therefore, grant applications are sought to develop advanced direct fuel injection systems that provide, at a minimum, a partial to fully vaporized homogeneous fuel-air charge at all times. Injection systems proposed must be low cost and perform equal to or better than existing systems.

c. Automotive Sensors—Information from automotive sensors is used for system and component diagnostics and for feedback control to improve vehicle performance and fuel economy, and to decrease emissions. To operate properly in the highly demanding automotive environment, many of the present on-vehicle sensors require significant advances in materials and device design. Innovative research is also needed for the development of new automotive sensor architectures for electric and hybrid vehicles. Grant applications are sought for improved electrical sensors for mechanical measurement, as well as sensors that measure charge, potential, potential differences, conductivity, permittivity, etc. Grant applications are also solicited for advanced sensor architectures (hardware/software) that integrate different vehicle subsystems for sharing sensor information, allow for overall reduction of the total number of sensors, and increase functionality. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

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35. MATERIAL CORROSION PREVENTION FOR ABSORPTION CYCLE HEAT PUMPS AND CHILLERS

In recent years, significant advances have been made in the deployment of absorption cycle heat pumps and chillers for application in building HVAC systems. Many novel concepts for advanced absorption cycles promise to deliver significant improvements in energy performance over conventional heating, cooling, and refrigeration systems. These advanced cycles utilize ammonia/water and lithium bromide/water as thermodynamic working fluids in a broad range of mixture concentrations and at elevated temperatures (450-550 degrees Fahrenheit).

The primary limitation to achieving better performance with advanced absorption cycles is corrosion of the materials that are exposed to the high temperature ammonia/water and lithium bromide/water working fluids. However, if advanced absorption cycles are to become economically competitive with conventional heating and cooling systems, they must be able to be constructed using low cost carbon steel materials that are somehow protected from the corrosive effects of these advanced working fluids. This protection must be durable, low in cost, non-toxic, and must not degrade the thermodynamic performance of the working fluids.

Grant applications are sought only in the following subtopics. The first two subtopics deal with corrosion inhibitors for use with carbon steel exposed to working fluids that operate at high temperatures. The third subtopic deals with the magnetic treatment of carbon steel as a means of improving the effectiveness of protective coatings. The objective is to develop corrosion prevention techniques that will allow the use of low cost materials in advanced absorption cycle heat pumps and chillers.

a. Corrosion Inhibitors for Use with Ammonia/Water and Lithium Bromide/Water Working Fluids—Corrosion inhibitors are chemical substances that retard the corrosion of a metal in harsh environments when added in small concentrations. The concentration required for corrosion prevention is dependent upon a number of factors including the presence or absence of chloride ions, oxygen content, temperature, pH (alkalinity), and fluid velocity. In a sense, a corrosion inhibitor can be considered as an anti-catalyst that retards rather than speeds up a reaction. There are numerous inhibitor types and compositions. Most have been developed by empirical experimentation, and many inhibitor formulations are proprietary so that their composition is not disclosed. As a result, the mechanism by which many commercially available corrosion inhibitors function is not completely understood. Nevertheless, it is possible to classify inhibitors into three categories: organic inhibitors, vapor-phase inhibitors, and inorganic inhibitors. Although corrosion inhibitors can be used to great advantage to suppress the corrosion of metals in many environments, there are certain limitations. Many inhibitors are toxic (e.g., arsenic salts), which limits their application in building HVAC systems. Many inhibitors lose their effectiveness over time and as the operating temperature of the working fluids increase. Also, the use of inhibitors can be quite costly. Grant applications are sought to develop corrosion inhibitors that will work effectively in the protecting carbon steel exposed to ammonia/water working fluids in absorption cycle heat pumps, and lithium bromide/water working fluids in absorption cycle chillers. Both systems operate at fluid temperatures in the range of 450-550 degrees Fahrenheit, and utilize a broad range of working fluid concentrations.

b. Corrosion Inhibitors for Use with Hydronic Heat Transfer Fluids—Absorption heat pumps using ammonia/water absorption fluids may utilize a secondary heat transfer fluid between the absorption sealed system (which contains the ammonia refrigerant) and the indoor and outdoor heat exchange coils. Traditionally, glycol/water solutions (e.g., anti-freeze) have been used for this heat exchange between the absorption sealed system and the indoor coil for absorption chillers. However, glycol/water solutions do not work well in heat pumping applications because the glycol/water solutions become too viscous at low ambient temperatures. Potassium acetate has been proposed as a good heat transfer fluid because potassium acetate does not become so viscous at low ambient temperatures compared to glycol/water solutions. Unfortunately, potassium acetate causes excessive corrosion when used with the mild steel components in ammonia/water absorption heat pumps. Grant applications are sought to develop low-cost corrosion inhibitors that will work effectively in the

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protecting carbon steel exposed to potassium acetate hydronic fluids used in ammonia/water absorption heat pump applications. Grant applications are also sought for alternative hydronic fluids that exhibit low corrosion when used with mild steel, so long as the alternative hydronic fluid has desirable heat transfer and viscosity characteristics comparable to or better than potassium acetate.

c. Magnetic Treatment and Protective Coating of Base Metals—Base metals may also be protected from corrosion by a combination of surface pretreatment and coatings. Relatively thin coatings of metallic, inorganic, and organic materials are candidates for providing a satisfactory barrier between the metal and the corrosive working fluids under consideration for advanced absorption cycle heat pumps and chillers. Presently, metal coatings are applied by several methods including electro-deposition, flame spraying, cladding, hot dipping, and vapor deposition. However, all of these methods are subject to thermal stress failures as the operating temperature cycles up to very high temperatures. Grant applications are sought to develop a new, low cost, process in which a magnetic field is applied to carbon steel in order to attract metallic ions which would form a metallic coating adhering to the base metal. The process must also provide a residual magnetic field for retaining the magnetic coating, which would be opaque to any corrosion initiators such as the working fluids. The treatment must eliminate porosity and the forming of other defects as well as provide a thin layer of metallic coating without special processing. The resultant coating must be able to withstand temperature cycling and resist surface cracking so that corrosive substances would not come into contact with the metal surface. The coating must be designed such that it will not be affected by later stages of assembly or by combination with other components of the full system.

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* See Section 7.1

36. COATINGS FOR DIE CASTING DIES

Although the U.S. metalcasting industry is one of the largest recyclers in North America, saving 13.3 million tons of scrap metal from disposal and reusing 92 million tons of sand every year, the industry still produces about 15 million tons of solid wastes annually, including eight million tons of spent sand, nearly four million tons of slag, and two million tons of particulate. In response to the Metal Casting

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Competitiveness Research Act (P.L. 101-425), the Department of Energy established the Metal Casting Competitiveness Research Program (MCCRP) to perform and promote research and development (R&D) related to the technological competitiveness and energy efficiency of the U.S. metal casting industry. Since 1990, the MCCRP has provided $11.7 million in funding for 35 R&D projects. Among the challenges which the industry listed for itself in the document, "Beyond 2000: A Vision for the American Metalcasting Industry," was the following: "Develop advanced manufacturing technologies to increase productivity 15%, reduce average lead times 50%, and reduce energy consumption 3-5%."

This topic addresses this challenge by seeking ways to increase the lifetime of die casting dies, produced by this industry for casting products. These dies, which are very expensive to produce, fail prematurely from thermal fatigue cracking when the dies are exposed to reactive molten metals while operating under cyclic mechanical and thermal loading. These thermal fatigue cracks are accompanied by the presence of residual tensile stresses, corrosion of the die surface, or oxidation of the metal, and are accelerated by the high temperature of the die. Since most of the damage occurs at the contact surface of the die with the molten metal, this topic focuses on the development and application of coatings to protect these dies. **Grant applications are sought only in the following subtopics:**

a. Plasma Ion Implantation Coatings for Die Casting Dies—Plasma ion assisted implantation treatment is a candidate for improving the crack resistance of die casting dies. The presence of the added ions would harden the surface by reducing the residual tensile stresses or even introducing compressive stresses which must be overcome in order for cracks to spread. The composition of this coating could also be customized to increase the corrosion resistance of the die. This process provides an opportunity to significantly extend the useful life of die casting dies. Therefore, grant applications are sought to develop techniques for applying plasma assisted ion implanted coatings to die casting dies in order to significantly increase their useful life.

b. Other Coatings for Die Casting Dies—Since most of the damage occurs at the contact surface of the die with the molten metal, grant applications are sought to develop other coating technology for die casting dies. The coating should enhance the resistance of the die surface to soldering, erosion, oxidation, and heat checking. The resultant coatings must also be able to withstand the harsh environment of die casting, including repeated exposure to heating and cooling cycles, without cracking or spalling. Areas of interest include the development of both coating processes (e.g., CVD, PVD) and materials (e.g., diamond, ceramic, composites). The properties of the resultant coating must be well characterized (in terms of chemical, physical, surface properties, etc.). Furthermore, the coating must be carefully selected and applied so that it would not interfere with any welding or polishing operations used to correct minor damage in the dies.

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   http://www.oit.doe.gov/metalcast/mcvision.html
2. Metalcasting: Industries of the Future
   http://www.oit.doe.gov/IOF/metalcast

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3. Metal-Ion Implatation and Deposition Using Cathodic-Arcs
http://harry.lanl.gov/bpw/catharc.html

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* See Section 7.1

37. BIOMASS POWER

Biomass power (biomass-to-electricity power generation) is a proven electricity generating option in the United States. With about 10 GW of installed capacity, it is the single largest source of non-hydro renewable electricity. Of the 10 GW, about 7 GW are generated using forest product industry and agricultural industry residues, about 2.5 GW using municipal solid waste-based fuels, and 0.5 GW using other resources such as landfill gas. The 7 GW of traditional biomass capacity represents about 1 percent of total electricity generating capacity and about 8 percent of all non-utility generating capacity in the U.S. All of today's biomass power capacity is based on mature, direct combustion boiler/steam turbine technology. The average size of existing biomass power plants is 20 MW (the largest approaches 75 MW), and the industry average biomass-to-electricity efficiency is 20 percent. Nevertheless, a number of technical problems remain if we are to achieve the next generation of efficiencies and reach commercial viability of all biomass-based systems. Innovative ideas are needed for improved products that could later lead to rapid commercialization. **Grant applications are sought only in the following subtopics:**

a. Resource Production and Supply—Although at current levels of biomass power production, the supply of biomass residues can meet the demand for this fuel, biomass could provide a much larger portion of sustainable electric power supplies through the development of high yield crops dedicated to energy utilization. In addition, pressure is increasing on the power production industry to find ways to economically reduce carbon emissions in an environmentally sound manner. The utilization of energy crops could assist power producers in becoming more "green" while stabilizing the quantity and quality of their biomass resource. Fast growing crops have been under development for several years by the U. S. Department of Energy with an emphasis on switchgrass and poplars. However, the costs of production and supply remain too high to expect that they would enter the market as an energy resource in the near future.

Grant applications are sought to develop technologies for reducing the costs of production and supply of these crops in order to facilitate near-term commercialization. For example, one potential area of cost-reduction is the development of propagation methods for woody crop clonal material.

Grant applications are also sought to develop energy crops (other than switchgrass and poplars) that are economically viable for biomass power applications. While switchgrass and poplars are attractive species, an expansion in the range of energy crops that could be produced in a region could help avoid vulnerabilities due to factors such as pest infestation or weather variability.

Important factors in the selection of grant applications include the potential for increased yield and economic viability, the extent to which the entire production process is considered and optimized (for woody crop clonal material, this would include propagation of clonal material, material handling, and planting), and the involvement of private sector partners such as the nursing industry.

b. Resource handling and utilization—Reductions in the cost of electricity produced from biomass require improvements in material management systems for all types of biomass resources. Materials management starts with the harvest or collection of biomass resources, and also includes processing, drying, and feeding techniques. Grant applications are sought to develop innovative approaches for: (1) the collection, handling, storage, and transportation of residues; and (2) the handling, processing, and feeding of biomass materials (crops or residues) into power boilers or gasifiers. Because many different resource handling and utilization strategies would be appropriate for different combinations of power conversion technologies and biomass resources, grant applications must fully describe the type of power conversion technology (or technologies) and the biomass resource type(s) to be addressed, as well as the anticipated conversion efficiency. Areas of interest include efficient residue collection technologies and low-cost storage approaches that minimize biomass degradation; innovations

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in the storage of herbaceous material such as grasses; innovations in the harvest and transportation of whole-trees, wood chips, and grasses; and innovations that facilitate the feeding of a variety of biomass resources into combustion, gasification, or pyrolysis units.

c. Co-products—A large portion of biomass power is generated by using residues and wastes from the production of lumber and fiber products. In this sense, the generation of electricity is a "co-product" of the wood products industry. Conversely, the economic viability of biomass power would be enhanced by developing a dedicated crop, for the generation of electricity, which also produced a co-product of equal or lesser value. The following are existing or potential examples of co-products: (1) the production of a high-protein leaf meal for animal feed from (alfalfa) leaves, where the stems are used for power production; (2) the application of bioengineering or bioprocessing techniques to produce pharmaceuticals or speciality chemicals from biomass resources, where the low-cost fractioned components or processing wastes are used for power production; and (3) the development of methods for biomass ash utilization (ash utilization is also considered a co-product) including the utilization of coal ash and biomass ash which is mixed in cofiring applications.

Grant applications are sought for the joint production of electricity and one or more selected co-products using biomass resources. The potential economics must be clearly defined and explained including an analysis of potential markets, the feasibility must be evaluated, and the technical hurdles to producing both the electricity and the co-product must be resolved. Priority will be given to those grant applications with the greatest chance of resulting in near-term commercial ventures.

d. Modular Systems—There is a rapidly growing global market for modular biomass power systems in remote rural areas using small (10 kW to 200 kW) and larger units. In this context, the term modular refers to integrated systems that can be factory-fabricated and mass produced to lower capital equipment costs. Grant applications are sought to advance the economic competitiveness of modular biomass systems, utilizing technologies such as advanced fuel cell systems, sterling engines, micro-turbines, etc. Proposed systems must use indigenous biomass resources, have efficiencies significantly higher than existing biomass power options, and substantially reduce emissions associated with local power generation. Applications should fully describe the proposed system, scope of work, projected change in electricity cost compared to conventional systems, and projected emissions.

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   Bioenergy Information Network
   http://www.esd.ornl.gov/bfdp

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* See Section 7.1

** Available from Tennessee Valley Authority, Southeast Regional Biomass Energy Program, CEB 3A, P.O. Box 1010, Muscle Shoals, AL 35662-1010. Telephone 205-386-3086. Fax 205-386-2963. E-mail pcbadger@tva.gov

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PROGRAM AREA OVERVIEW - NONPROLIFERATION AND NATIONAL SECURITY

http://www2.nn.doe.gov/nn

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 both cooperative and non-cooperative environments, and on support to intelligence activities. 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 noncooperative environments; (3) address the proliferation of biological and chemical weapons by modifying and applying technologies developed for nuclear non-proliferation and by exploiting DOE expertise in the biological and chemical sciences and 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) maintain the technology base required to address emerging threats and other future needs.

38. ADVANCED TRANSPORTABLE ANALYTICAL AND COLLECTION TECHNOLOGIES FOR NONPROLIFERATION AND LAW ENFORCEMENT 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. It is necessary to have the capability to detect the production, storage, and transportation of such weapons. Particular needs include the detection and identification of Special Nuclear Materials, along with precursors and/or indicators of these materials. The development of miniaturized devices for sensing and detecting such weapons/materials is also a high priority.

DOE also has the responsibility for the physical security of its facilities, and when illicit activities occur, the clear, unambiguous attribution of these activities is required. This latter responsibility is common to both DOE and the law enforcement community.

This topic seeks research, engineering, and prototype development to meet these needs. **Grant applications are sought only in the following subtopics:**

a. Improved Quantitative and Separation Techniques for Particles—Current aerosol collectors/concentrators, components of air samplers used by the nonproliferation community to detect the presence of chemical or biological agents, are limited in their capabilities. Grant applications are sought to extend these limits. Desirable characteristics include: (1) an air sampling volume rate of 200 to 1,000 liters per minute, preferably adjustable; (2) a pre-fractionation system which rejects air particles larger than 15 microns, preferably with a virtual impactor rather than a filter, and traps them such that they do not re-aerosolize when the unit is physically disturbed; (3) a mechanism for passing the captured particles into a liquid such as distilled

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water, possibly containing a surfactant such as "0.01% tween 80," prefiltered to include only particles larger than 0.1 micron; (4) a capture efficiency greater than 80 percent for particles in the size range 0.1-10 microns over the concentration range of 0.001-10,000 particles per liter of air; (5) for particles between 10 and 15 microns, a capture efficiency which monotonically decreases from 80 percent at 10 microns to 0 percent at 15 microns; (6) a collection/concentration process which does not kill more than 20 percent of living biological particles such as viruses and bacteria; (7) a latency period, which is the duration between the time of sampling and the time when the aerosol pre-fractionation and liquid capturing circuits have been cleared to less than 1 percent of their peak concentration, that does not exceed 3 minutes (after 6 minutes, the concentrations should tail off to less than 0.01 percent of peak); (8) a capability for unattended operation for at least one week, with an option for battery operation for shorter time periods; (9) power consumption which does not exceed 30 watts; and (10) portability, with weight not exceeding 30 lbs. and the system packaged for ease of handling by backpack or suitcase.

b. Latent Image Visualization—A developed and identified image on material from a crime scene is perhaps the most powerful evidence linking a suspect to the scene. Latent images consist of water-soluble (amino acids, proteins, salts, etc.) and water-insoluble (lipids) materials. Most developmental work has concentrated on visualizing the water soluble portion of latent images. However, lipids are more abundant, and persons leaving indications do not always leave amino acid images but may leave lipid images. Also, latent images that have been water-soaked lose all their (water soluble) amino acids but not their lipids. Thus, more methods are needed to visualize the lipid portion of latent images.

Lipids are generally detected by physical (powder) or physiochemical (aqueous colloidal metal deposition) methods. However, with current aqueous (colloidal metal deposition) methods, it is difficult to see a developed lipid on very dark paper surfaces. Grant applications are sought for the development of chemical methods to detect water-insoluble lipids from latent images. One possible approach is the development of a reagent that chemically binds to lipids and forms a fluorescent product detectable through optical means.

c. Fieldable, Battery-Powered, X-ray Display, Recording, and Transmission Device—Grant applications are sought to develop a readily man-portable (25 pounds), low cost, 300 Kev X-ray imaging device capable of providing, recording, and transmitting an image in the field. Such a device would have application to law enforcement and border security, and would be useful to customs and other government agencies. The ability to collect and transmit, from remote locations, a high-quality image for analysis and evaluation in a laboratory would provide significant assistance to the inspector in the field. Medical applications, particularly in remote locations, would also benefit from the development of such an instrument.

d. High Speed Acousto-Optic Tuners—High repetition rate (greater than or equal to 10 kHz) carbon dioxide lasers require high speed acousto-optic (AO) tuners to rapidly and randomly access different laser lines (see references 1-2). Such tunable lasers would have application to the chemical analysis of effluents of concern to nonproliferation. Grant applications are sought for the development of acousto-optic tuners which work throughout the 8-12 micron region of the long wave infrared spectrum at line tuning rates of at least 100 kHz. The highest possible overall tuner efficiency is desired, including both high diffraction efficiency and low static losses at surfaces and in the bulk crystal. The tuners must have an intra-cavity round-trip transmission of at least 70 percent and low absorption to minimize thermal lensing effects. New design solutions are required to ensure that at least 50 percent of the heat load resulting from a radio frequency (rf) duty cycle can be dissipated without creating non-uniform temperatures within the crystal, which may otherwise lead to aberration of the acoustic and laser beams.

In addition to these requirements, improvements which make AO tuners simpler and more compact are desired. To first order, it would be beneficial to reduce the total crystal length to reduce absorption losses and optical propagation distance, while keeping diffraction efficiency high. A more advanced concept would use a single crystal containing counter-propagating acoustic beams, either separated or overlapped in space, to both up- and down-shift the frequency of the laser beam. This would require maintaining separate

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transducers for the two acoustic beams so that, by introducing a phase shift between the rf signals and the two transducers, the effective laser cavity length could be rapidly adjusted. Such a device might incorporate a high-reflecting resonator mirror to further decrease device size, coating losses, and beam propagation distance. In order to reduce the required optical beam size as well as the overall device size, it would be desirable to increase the current 80 MHz center rf frequency by at least 50 percent.

Alternate concepts for laser tuners which meet the above requirements are also of interest. Applicants must also indicate which of the desired improvements will be addressed in Phase I and which will be addressed in Phase II. It would also be considered advantageous to work with a laser laboratory that can test the tuners.

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39. SAFEGUARDS, SECURITY, AND MATERIAL ACCOUNTABILITY FOR SPECIAL NUCLEAR MATERIAL

The United States Department of Energy, and several international organizations, have immediate needs for improved techniques for safeguards, security, and material accountability for special nuclear material (SNM). Several studies have emphasized the difficulty of detecting, and interdicting SNM in transit and at international borders and checkpoints. This topic seeks innovations in software and hardware to address these needs. **Grant applications are sought only in the following subtopics:**

a. Software for an Integrated, Automated System for Safeguards, Security, and Material Accountability—Safeguards procedures, security measures, and material accounting are often applied independently of one another, and a systems approach is required. Grant applications are sought for computer software which integrates safeguards, secrity, and material accountability using "smart" technology. The technology must include expert or learning systems, neural nets, or automated hierarchical decision making. Inputs from a variety of detectors (motion, temperature, pressure, video, etc.) must be integrated to provide for automatic entry of information into accountability systems, activation of mechanical locks, and maintenance of a record of actions taken and personnel involved. Phase I should include the design of the software and a proposed experiment. Phase II should extend the design to prototype development and demonstration.

b. Miniature Accelerator for Safeguards Applications—A small linear accelerator is needed to enhance the analysis of non-homogeneous mixtures of SNM. Grant applications are sought to develop a rugged, well-collimated (or highly focused) 10 Mev pulsed accelerator, with a 2 kW power supply, which is capable of being operated with minimal training. The accelerator must provide a source of radiation which could be used to identify the characteristics of SNM, and to distinguish SNM from substitute materials. The device should also provide a signal for incorporation into an automated safeguards, security, and accountability system. Phase I should include the design of the system and the specification of an experiment to demonstrate the capabilities of a prototype which would be developed under Phase II.

c. Low Vibration, Liquid Helium Temperature Cryo-Coolers—High sensitivity radiation and infra red detectors require cooling to very low temperatures. Dewars are not suitable for many field applications, and cryo-coolers tend to suffer from vibrations which reduce the sensitivity and degrade image quality. Grant applications are sought for the

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development of a low-vibration cryo-cooler (see references 1, 2, 5) system to supply 1 W of cooling power to a detector while damping vibrations so that the 3 sigma displacement is less than 2.5 microns. The cryo-cooler must be able to maintain the detector at a temperature of 10 K (or better) after cooldown. It is desirable that the cryo-cooler be designed to maintain a stable temperature between 4 K and 50 K as set by the user. Either active or passive damping is acceptable, but the system must be fieldable. The Phase I work should design the cryo-cooler and perform risk-reduction experiments. The Phase II work should build a cryo-cooler and then perform a thorough test program to validate that it meets specifications.

d. High Speed Detector Arrays with Integral Readouts—Low noise detection of optical radiation in the 3-5 micron region is a potential means of motion detection. Grant applications are sought for the development of high-speed single element and multiple element detector arrays with integral (or hybrid) readouts (see references 3, 4, 6). Element sizes must be between 20-100 microns and the detector and supporting electronics must satisfy a requirement for low readout noise. For example, the readout noise must be less than 50 electrons with the following parameters: detector size of 50x50 micron element; quantum efficiencies in excess of 0.7; integration times of less than 100 nanoseconds to control background noise; and a readout and recovery time of 6 microseconds or less. For other element sizes, the noise requirement scales in proportion to the area. Of special interest would be 3x3 to 5x5 arrays that are uniform with fill factors of 60 percent or greater. Pulse integration could be performed on-chip or, because of the small array size, could be done serially off-chip on the amplified signal. Correlated double sampling is a required feature. The entire array must be read out and recovered within the 6 microsecond recovery time. Phase I work should demonstrate performance on a single element, and the Phase II effort should demonstrate the array.

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