DOE/ER-0686

CYCLE 15

SMALL BUSINESS INNOVATION RESEARCH

PROGRAM SOLICITATION

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

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TECHNICAL TOPIC DESCRIPTIONS

The technical topic descriptions for this solicitation are given below. The text in the first section of each topic gives general and background information for the topic. Within a topic, there are 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.

1. REMEDIATION OF SUBSURFACE CONTAMINANTS

Nearly all 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 methods are needed for containing concentrations of contaminated materials which provide a long term source for 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 that also extend underneath the zone to serve as both a floor and a lateral barrier. Grant applications are sought for (1) reactive barriers which retain only contaminants and allow uncontaminated ground water to pass through the barrier, and (2) alternatives to baseline technologies for landfill covers.

b. Source Remediation—Grant applications are sought for innovative methods for remediating source areas which provide contaminants to ground water and soils beyond the source area over extended periods of time. These sources include landfills, leaching pits, burning grounds, and disposal cribs and contain a variety of contaminants such as organics, inorganics, radioactive species and mixtures of these contaminants. As part of DOE's strategy for contaminant plume remediation, these sources need to be remediated prior to actual remediation of the plumes. Specific areas of interest include *in situ* stabilization, *in situ* treatment, and technologies that are capable of removing valuable contaminants for reuse.

c. DNAPL Remediation—Dense Non-Aqueous Phase Liquid (DNAPL) plumes are a major environmental problem across the DOE complex and are common problems associated with industrial sites. Grant applications are sought for innovative methods to remediate soils and 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 that will allow the DNAPL contaminants to be removed or destroyed without extensive excavation (which would result in increased environmental damage and worker exposure potential).

d. Metals and Radio Nuclides—While metals contamination is common in the private sector, radio nuclide contamination is almost unique to DOE. Grant applications are sought for innovative methods for remediation of soils and ground water contaminated with metals and radio nuclides. 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 that immobilize the contaminants in place or that render the metal environmentally safe by altering its chemical state or availability.

Because many metal and radio nuclide contaminants are valuable as resources, grant applications are also sought

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for technologies which would recover these contaminants for reuse or sale.

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5. PFA: Plumes Focus Area, "National Technology Needs Assessment," Review Draft, U.S. Department of Energy, May 17, 1996.**
6. Plumes and Landfills Stabilization Focus Areas, Progress Report, U.S. Department of Energy, Winter 1996.**

* See Section 7.1.

** Available from the Subsurface Contaminant Focus Area Manager, Savannah River Operations Office, P.O. Box A, Aiken, SC 29802. Telephone 803-725-5534.

World Wide Web Information:

1. "Contaminant Plumes Containment and Remediation Focus Area"
   http://www.em.doe.gov/rainplum/index.html

2. CHARACTERIZATION TECHNOLOGIES FOR ENVIRONMENTAL REMEDIATION AND WASTE MANAGEMENT

The Environmental Restoration Remedial Action Program assigns DOE contaminated sites to a group of problem sets, which are defined by specific contaminants and media. The contaminants consist of volatile and semivolatile organic compounds (SVOCs and VOCs), metals, radionuclides, mixed low-level waste, and mixed transuranic waste. The media consist of ground water, surface water, waste water and liquids, solids and debris, soil and sediment, and sludge. Various *in situ* and *ex situ* treatment processes are identified for each problem set, and they include chemical, physical, thermal, and biological processes. The new vision of the DOE Environmental Management program calls for achieving complete cleanup of most DOE contaminated sites by the year 2006 (the 10-year plan), with only a few special waste streams and surveillance and maintenance operations remaining after that period. The scope and schedule of activities, the volume of wastes, and the need to reduce costs will increase the strong demands for sensors to monitor, in real time, the efficacy of remediation processes. In addition, sensors for long-term, *in situ* monitoring are required for automated and unattended monitoring of the migration of contaminant plumes, as well as for monitoring contaminants that breach containment and confinement operations.

Grant applications must address the durability and ruggedness of proposed sensor technologies in the intended operating environment and media. Performance goals for the proposed technology development (i.e., the constituents or parameters addressed, and the target limits of detection, accuracy, precision, response time, and target measurement ranges, etc.) must be clearly stated and consistent with the functional and operating requirements of the prospective customer(s). Information concerning the baseline technology (if any) and its performance must be provided so the potential value of the proposed technology development can be assessed. **Grant applications are sought only in the following two subtopics:**

a. Sensor Technologies for Real-time Monitoring of Treatment Processes—Contaminants for treatment at DOE sites consist mainly of the following: halogenated VOCs (i.e., trichloroethylene), perchloroethylene (PCE), carbon tetrachloride, and chloroform); SVOCs (primarily polychlorinated biphenyls); heavy metals (i.e., Hg, Pb, Cr^{VI} and Cd); radionuclides (i.e., Pu, U, Am, Th, Tc, ^{90}Sr, ^{137}Cs, and ^{3}H); and combinations of the above. Common treatment technologies to remove or stabilize these contaminants include soil vapor extraction, thermal desorption, air stripping, carbon adsorption, biodegradation, UV oxidation, and incineration for VOCs and SVOCs; solidification stabilization for metals and radionuclides in soils; precipitation, filtration, and ion exchange for metal and radionuclide removal from groundwater.

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Grant applications are sought to develop sensor technologies for use with these treatment processes, and for real-time assaying and segregating of waste soils from nonwaste soils for treatment. Applicants are expected to be thoroughly familiar with current waste segregation and treatment processes, their operating parameters and data requirements. Grant applications must define and document, where possible: (1) the proposed sensor locations in a treatment process flowsheet, (2) the compatibility or stability of the materials of construction in the proposed operating environment, and (3) the integration of sensor signals with process control and optimization instrumentation.

b. Sensor Technologies for Long-term Monitoring of Contaminants in the Subsurface—Advanced systems for preventing subsurface contaminants from migrating out of their confinement zones include (1) manufactured geosynthetic clay liners for waste site covers or caps in order to block the infiltration of rain waters and snow melt into the waste, and (2) various barrier walls including grout, slurry, and plastics with minimum leachability. Long-term performance monitoring is needed to assess the adequacy of these confinement techniques as a viable alternative to the waste treatment and removal operations. The data can be used to determine the integrity of covers, caps, and barrier walls, as well to understand transport mechanisms is required for a risk-based determination. Grant applications are sought to develop sensor technologies for (1) determining the location and magnitude of barrier discontinuities as a result of intermittent emplacement and improper curing or temperature cycling of barrier materials; (2) long-term monitoring of moisture leakage through geosynthetic clay liner barriers as landfill covers; (3) incorporating sensors into liner or barrier wall materials to monitor incipient flaws and long-term stability; and (4) monitoring the leaching and breaching of contaminants through barrier walls over long periods. Grant applications are also sought for technologies to emplace sensors in the subsurface for long-term, unattended monitoring of the migration of contaminant plumes in soils and groundwater for risk assessment. Grant applications must define and document, where possible: (1) how sensors will be deployed in the subsurface or incorporated into liner and barrier materials, (2) how the systems will be calibrated, and (3) how automated, unattended data acquisition will be accomplished for long-term performance monitoring.

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* See Section 7.1.

3. EFFICIENT SEPARATIONS PROCESSES

The DOE's goals for waste management and environmental restoration are to (1) reduce the volume of waste that must be disposed of in a geologic repository; (2) decrease the toxicity and minimize the quantity of low-level waste (LLW) that is disposed of near the earth's surface; (3) minimize the volume of process, secondary, and decontamination and decommissioning wastes; (4) modify and apply separations methods developed for waste treatment to environmental restoration and waste management activities in remediation of soils and groundwater; (5) identify high-value waste constituents

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for potential recycle; and (6) develop technologies for transfer to commercial use.

Separation technologies can remove radio nuclides, hazardous materials, and chemicals from radioactive wastes (see note below), contaminated soils and groundwater, and waste streams resulting from the decommissioning and decontamination of facilities contaminated with hazardous and/or radioactive chemicals. Heavy metals, Resource Conservation and Recovery Act (RCRA) metals, organics classified as hazardous by the RCRA, and radioactive species are typical components of concern in DOE waste streams. Separation technologies must minimize the environmental impact, risk, and life cycle costs of waste treatment, waste disposal, and environmental restoration.

[NOTE: Radioactive wastes can include high-level wastes (HLW), LLW, transuranic (TRU) wastes, and highly radioactive mixed wastes. HLW is defined as the highly radioactive waste material that results from reprocessing spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation. TRU waste is defined as waste that is contaminated with alpha-emitting transuranic nuclides with half-lives greater than 20 years and concentrations greater than 100 nanocuries per gram of waste. LLW is defined as radioactive waste not classified as HLW, TRU, spent fuel, or by-product material. Mixed waste contains both radioactive and hazardous components, as defined by the Atomic Energy Act and RCRA.]

Grant applications, submitted in response to the subtopics listed below, should identify separation processes which are selective for specific contaminants of interest; produce low-volume secondary waste streams; and provide high loading capacities, high separation factors, and simplicity. Separation processes having commercial applications are strongly encouraged, but all grant applications should target a DOE problem. Enabling processes for separations (i.e., processes which transform the waste stream so that it becomes amenable to subsequent treatment by an established or innovative separation process) are also acceptable. In all cases, the flexibility of the technology is important; for example, a technology that addresses multiple contamination situations is preferable to a technology limited to a single situation. Grant applications should describe clearly the advantages of the proposed technologies over existing alternatives, if any.

For those applicants who do not have the facilities to perform research involving radioactive species, grant applications will be accepted in which an innovative separation technology is demonstrated on a nonradioactive substance; however, the approach, upon further development, must be relevant to radioactive species. **Grant applications are sought only in the following subtopics:**

a. Concentrated Aqueous Waste Streams—Nitrates and nitrites constitute the largest fraction of wastes at some DOE sites, increase volume and cost requirements, increase safety risks, complicate waste processing, and can increase the leaching of other components from waste forms. Hazardous organics pose serious environmental threats and can reduce the effectiveness of some methods for removing metals from waste streams. Grant applications are sought for innovative methods for (1) separating radioactive species from high ionic strength, multi component, aqueous solutions of salts dominated by species such as sodium nitrate, nitrite, carbonate, and phosphate; and (2) the removal and/or destruction of non-radioactive but problematic compounds such as nitrates, nitrites, and organics (especially RCRA-related organics) in radioactive wastes, and the removal of fine solids or colloidal particulates (which can carry a large fraction of contaminant and can interfere with subsequent processing). Treatment of both acidic and alkaline (up to several molar in hydroxide) aqueous solutions are of interest.

b. Dilute Aqueous Waste Streams—Grant applications are sought for separation or enabling processes to remove contaminants from dilute aqueous streams such as groundwater (in situ or pump and treat operations), streams arising from decontamination and decommissioning operations, and slightly acidic off-gas scrub solutions. Radionuclides and other materials under consideration for separation include RCRA and heavy metals (thorium, mercury, chromate, chromium (III), lead, cadmium, and copper), RCRA organics, transuranic (TRU) elements such as neptunium, plutonium, americium and curium, long-lived soluble fission products including technetium (^{99}Tc) iodine (^{129}I), and activation products such as carbon (^{14}C) - separation of the activation product tritium is considered under subtopic 'd'. Typical contaminant concentrations are on the order of 0.1-10 ppm and proposed technologies should offer advantages over existing sorption or precipitation/filtration processes. Innovative separation methods could involve 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

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complexant need to be considered for an integrated loading-elution-disposal sequence. Technologies for the removal of fine solids or colloidal particulates will also be considered.

c. Solid Wastes—Solid wastes include sludges from defense reprocessing activities, solids such as metals and concrete from decontamination and decommissioning operations, and excavated soils from environmental remediation activities. Highly radioactive sludges are typically metal oxides with large amounts of potentially soluble materials such as sodium or aluminum. Only about 0.3 percent of the waste is radioactive. 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. Methods such as bulk leaching, selective leaching 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. Grant applications are sought for innovative ways to remove contaminants selectively and efficiently from soils while removing as little non-contaminant material as possible.

Grant applications are also sought for high temperature and chemical methods to separate radionuclides and hazardous elements from solid (e.g., calcined) radioactive waste streams. Of particular interest are processes that separate species into concentrated products streams that can withstand a radiolytic environment, are economically viable, can be scaled to processing rates of 2 to 30 gallons per minute, and are simple to construct and operate. Reagents that can assist in the electrokinetic decontamination of soils and concrete are also of interest.

d. Tritium Removal—Grant applications are sought for efficient technologies to remove diluted tritium (present as hydrothermal oxidation (HTO)) from large volumes of water, such as storage pool water, groundwater, or process wastes. As examples, tritium concentrations of 10,000,000 to 200,000,000 pCi/L exist, and the K-East Basin at the Hanford site contains a million gallons at a concentration of 3,000,000 pCi/L. Thus, HTO concentrations corresponding to mole fractions in water of 10^{-14} to 10^{-10} need to be treated. Treated water should have tritium concentrations not exceeding the drinking water standard (20,000 pCi/L). Proposed technologies should be compared in terms of economics and performance to existing technologies, such as separations based on hydrogen sulfide exchange or catalyzed hydrogen-water exchange.

Vacuum pump oil at Savannah River also contains tritium, and innovative technologies for its removal are also sought.

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* See Section 7.1

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4. GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

The 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. System Integration, Software, and Technologies that Support DNA Sequencing and DNA-Based Diagnostics—Increased use is being made of DNA sequencing in biotechnology, genetic toxicology, medical applications, and environmental applications. Data derived by *de novo* DNA sequencing have wide application in a variety of research areas (e.g. protein structure/function, understanding all the components in a biological pathway, genetic disease characterization, finding enzymes with useful catalytic properties from microorganisms, etc.). Data derived from DNA sequence-based diagnosis and screening technologies also has wide applications (e.g., studies of human gene polymorphism and DNA damage, monitoring food for pathogens, environmental monitoring, etc.)

Grant applications are sought for improvements in software and instrumentation to substantially augment present capabilities in DNA sequencing technologies or DNA sequence-based analysis software. Applications must significantly improve, integrate, or automate several steps associated with large-scale DNA sequencing or DNA-based screening. Areas of interest include innovative approaches to increase the speed of sequencing, analysis, and other steps by orders of magnitude, while maintaining performance and low cost; and high-throughput methods to determine the sequences of many samples in parallel. Developments might include: (1) novel automated and integrated instrumentation for DNA preparation, amplification, and mapping; (2) improved instrumentation or analysis of the signals from the sequencing instruments; (3) determination of appropriate sequencing templates from the physical map of a genomic region; (4) automation of handling and processing of the results from the DNA sequencing instruments; (5) improved systems for interrogation and cross correlation of DNA clone libraries; (6) prediction of meaningful sequence similarities between newly discovered sequences and the sequences of previously characterized genes; (7) automation of sequence data analysis and annotation; and (8) submission of sequence and associated data to community databases. Applications must describe the requirements and nature of sequencing centers or other user communities that will be the initial beneficiaries of these innovations. Applicants are also encouraged to interact with potential end-users.

b. Access and Analysis Tools for the Biological Data in Large Public Databases—Large, complex public databases and data resources now play an increasingly important role in biological research, with access and analysis of the data critical to genome, structural biology, and other research fields. In addition, analysis tools that implement computational genomics, computational structural biology, and other research are needed for these data. The public data resources include the Genome Sequence Data Base, the Genome Data Base, Nucleic Acid Structure Database, Protein Data Bank, and Phylogeny, Metabolism, and Alignment database. The databases are, for the most part, available on-line over the Internet via documented application programming interfaces. Software tools are needed to facilitate access to distributed, heterogeneous data bases so that biologists can extract meaningful information. Recently, the World Wide Web file-based information access and hyperlinks through the Internet have proven very useful. Improved methods for automated analysis are also needed. The analysis of data held in multiple databases may involve additional research and development, such as techniques for data mining or other methods of extracting useful information.

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Grant applications are sought for innovative design, evaluation, or optimization of software to facilitate the analysis and handling of data held in public biological data resources. Areas of interest include: (1) vector graphics displays of genomic maps and other biological data; (2) improved ability to direct ad hoc structured queries against underlying public biological databases; (3) improved ability to execute sophisticated queries, data mining, or other information analysis using data from multiple databases; (4) integration of local laboratory data with data from networked public databases; (5) improved data analysis, data annotation, data curatorship, and database submission tools; and (6) better analysis and integration of the functions, sequences, structures, and other information about genes, the corresponding gene products, and the biological pathways in which the gene products function. Applications must have Internet-accessible tools (the only exceptions are CD-ROM-based applications, assuming that use of the latter mode of distribution is strongly justified by user requirements); demonstrate familiarity with previous and current work in the area; develop interactions with one or more existing research sites already active in computational biology or biological data resources; and address scale-up to large scale genome analysis. Grant applications must adequately describe the project plan, the user communities that will be the initial targets for these innovations, as well as the user and system requirements for the project.

c. Computational Biology and the Protein Structure—An understanding of how proteins form three-dimensional structures is critical for some industrial, medical, and environmental applications of biotechnology. Advances in genomics will provide many primary gene structures (e.g., the nucleotide and amino acid sequences), predicted gene products, and known proteins, but will not directly address the secondary or tertiary structures of these biological macromolecules. Understanding the relationships between sequence and structure and how to engineer new or altered structures will be needed. Advances in computational structural biology, along with some input from computational genomics, are needed to fully exploit some of the rapidly expanding data from genomics research.

Grant applications are sought to develop computational software tools or analysis methods that will advance the understanding of protein structure. Applications should address the protein folding problem or related computational structural biology problems but may also interface with computational genomics. Areas of interest include the development and implementation of new or improved algorithms for extending the knowledge of protein folding mechanisms, and the development and improvement of software for visualization and graphics for application in protein folding prediction or determination. Examples of existing approaches to these problems include knowledge-based or molecular extension methods (e.g., homology model building or multiple sequence alignment), *ab initio* folding (finding structures that fit sequences), and the development of tools to assign existing or new sequences to specific structures (e.g., finding sequences that fit structures through threading or inverse folding algorithms). Issues that could be considered in the application include multiplatform support, Internet accessibility, and integration with data held in the PDB or other community databases. Grant applications must adequately describe the project plan, the user communities that will be the initial targets for these innovations, and the user and system requirements for the project. Applicants should also demonstrate extensive knowledge and experience in use of such methods for protein folding.

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World Wide Web Information:

1. Department of Energy Office of Health and Environmental Research
   http://www.er.doe.gov/production/oher/oher_top.html
2. European Molecular Biology Laboratory
   http://www.embl-heidelberg.de/
3. Genequiz
   http://www.embl-heidelberg.de/~genequiz/
4. Genome DataBase (GDB)
   http://gdbwww.gdb.org/
5. Genome Sequence DataBase (GSDB) at the National Center for Genome Resources
   http://www.ncgr.org/gsdb/gsdb.html
6. Human Genome Program Information
   http://www.ornl.gov/TechResources/Human_Genome/home.html
7. Johns Hopkins University Bioinformatics Server
   http://www.gdb.org/hopkins.html
8. Protein Data Bank
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   http://www.mcs.anl.gov/home/compbio/PUMA/Production/puma_graphics.html
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    http://www.ncbi.nlm.nih.gov/
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12. The University of Minnesota Biocatalysis/Biodegradation Database
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5. ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

Characterization of subsurface, atmospheric, and oceanic environments is a key element of several 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

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measurement of biological and physicochemical properties of natural systems with low-maintenance or autonomous sensors and equipment. 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 play 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, 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. The 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. The proposed technologies must significantly reduce remediation duration and/or costs through advancements in the methodologies used to monitor, analyze, or control the remediation process; and (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.

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

d. Fiber Optic, Solid-State Chemical, and Silicon Sensors—Fiber optic sensors (classified as intensity-based, 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 that 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 is considered responsive to this subtopic. Minor adaptations of readily available materials or hardware for such use are not responsive to this subtopic. 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.

6. 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 four subtopics focus on these needs. Subtopic 'a' concerns the development of sensor and launch systems for balloon sondes. Subtopic 'b' relates to the development of a 10 micrometer radiometer for cloud base temperature and emissivity measurements, while subtopic 'c' pertains to the design of novel microwave radiometers for water vapor concentration and temperature profiling. Finally, subtopic 'd' concerns the development of new radiometric instruments.

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

a. High Accuracy Sensor and Automatic Launcher System for Routine Balloon-Borne Measurements of Atmospheric Thermodynamic Properties—High accuracy measurements of atmospheric parameters are required from lightweight, low cost, high precision instruments to support atmospheric and climate research. A need exists for a cost effective capability to launch a series of balloons with sensors over periods of time, i.e., a day or days, at unattended locations. Research and development is needed for both the sensor and launcher aspects of this problem.

Grant applications are sought to develop sensors for high accuracy, fast response 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. For water vapor, a fundamentally new approach is required to provide high accuracy measurements to very high altitudes and temperatures down to at least minus 60 degrees centigrade; one percent accuracy with high time resolution for relative humidities near 100 percent at minus 60 degrees is

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highly desirable. While the development of new water vapor sensors are of interest, integration into a light, cheap, and environmentally sound sensor package must be demonstrated. Sensor packages must be expendable, must not exceed the current radiosonde weight of about 8 ounces and must be packaged in an infrangible structure suitable for routine use in general aviation airspace. If the system is dependent on available navigation systems, use of the Global Positioning System is required. Reflecting the large number of launches desired, a total unit cost near that of current sondes is also desirable.

Grant applications are also sought to develop a balloon launch system, for unattended locations, that can successfully launch a minimum of 8 sondes in succession, acquire the data from each flight, and make the data available for network data transfer to a centralized data acquisition facility. Because existing balloon sounding launches are labor intensive, the balloon launch system must not require reloading any more frequently than once a day during periods of high launch rates (nominally every three hours).

Applications that make only incremental improvements to existing technologies will be declined.

b. 10 Micrometer Radiometer for Cloud Base Temperature and Emissivity—High altitude, tropical cirrus, which can exist at temperatures as low as 150 degrees kelvin, is not well understood nor modeled. Ten micron radiometric measurements of cloud base emissivity have proven valuable to modeling cirrus properties in mid latitudes. Grant applications are sought to develop 10 micrometer radiometers for the continuous measurement of cirrus cloud base temperature and emissivity, especially for high altitude cirrus in the tropics. These measurements are important for the development of new algorithms and models for the general circulation models used for climate research. Continuous operation of such radiometers and use in remote locations requires the absence of liquid cryogenic materials and a design that accommodates routine environmental conditions, e.g., rain, wind, dew, etc. Applications that make only incremental advances to existing technologies will be declined.

c. Microwave Radiometer for Water Vapor Concentration and Temperature Profiling—Grant applications are sought to develop a microwave radiometer for continuous, cost effective profiling of water vapor concentrations and temperatures from below 1 kilometer altitude to altitudes above 10 kilometers, with height resolution of 100 to 200 meters below an altitude of one kilometer and 500 meters above one kilometer. Unattended operation for prolonged periods of time (nominally weeks) without degradation of the measurement must be demonstrated. The design of the system must accommodate exposure to the full range of normal environmental conditions, e.g., dust, rain, snow, etc. Minor adaptations to existing technologies will not be considered responsive to this subtopic.

d. 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 broad-band 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 for the development of novel radiometric instrumentation or radiometer components that (1) improve current performance (e.g., eliminate angle of incidence, temperature, pressure, and humidity effects on detectors, precision optical components, and windows; (2) reduce drift or calibration requirements; (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.

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* See Section 7.1

7. MEDICAL APPLICATIONS

The 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 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) boron-labeled compounds that are capable of concentrating in tumor cells *in vivo* and delivering lethal radiation after neutron irradiation. Radiochemical, synthetic, and molecular approaches should be given consideration in developing molecular medicine technologies capable of providing a product for nuclear medicine use.

b. 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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8. OCCUPATIONAL EXPOSURE ASSESSMENT

As in many industries, some of DOE's research, development, manufacturing, and clean-up operations are potentially health hazardous. Occupational exposure assessment is an important, but often costly component of health protection programs that manage the risks associated with these operations. Occupational exposure assessment is accomplished through monitoring the work place environment and measurement of the appropriate determinants in biological specimens. The primary purpose of the monitoring is to quantitatively characterize the exposures of individual workers. While mature technologies exist for many hazardous agents, such as ionizing radiation, for others the lack of simple cost effective monitoring methods create a significant barrier to routine assessment of individual workers' exposures.

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The changing DOE mission has created a higher degree of uncertainty about the risk associated with its operations, making improved exposure assessment especially important. Routine exposure assessment helps workers and their supervisors modify work practices and equipment to minimize exposures. It also allows medical personnel to determine whether health events occurring in the work force are related to exposures occurring in the place of employment.

The DOE needs to develop exposure assessment techniques or capabilities for specific hazardous agent(s) for which current capabilities are limited due to the lack of exposure assessment methods or prohibitive costs. Grant applications must describe the specific hazardous agent(s) to be addressed, the currently available exposure assessment techniques, and the proposed measurement technologies to be developed. Grant applications must include the testing methodologies for these exposure assessment techniques that will be employed to determine their feasibility. Applicants must also submit information supporting their capability to perform follow-on development and validation of the exposure assessment technologies (for example, the capability to generate known aerosol concentrations or access an appropriate animal model.) **Grant applications are sought only in the following subtopics:**

a. **Personal Monitoring**—Small, wearable, autonomous, and low maintenance monitors are lacking for many health hazardous chemicals and energy forms, such as toxic metals and magnetic fields. This is contrasted by the availability of monitors for hazards such as penetrating ionizing radiation and organic solvents. Within DOE, potential aerosol exposures are a common hazard where routine personal monitoring remains difficult and costly. Costs associated with the chemical analyses can also be a significant barrier to routine monitoring. Grant applications are sought to develop monitoring equipment or analytical methods, either of which would significantly reduce the level of effort and costs associated with routine personal monitoring.

b. **Biological Monitoring**—Currently there are only a limited number of bio-assay and bio-marker tests available that are useful for estimating an individual's exposure to health hazardous chemicals and energy forms (see references 1, 3 and 4.) Grant applications are sought for new, safe, non-invasive tests for determinants of exposure in biological media such as blood and urine. Applicants proposing to use human subjects must submit information supporting their capability to comply with DOE regulations for the protection of human subjects. Applicants proposing to use vertebrate animals must submit information supporting their capability to comply with Department of Agriculture regulations and National Institute of Health guidelines on the treatment of laboratory animals.

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9. BIOLOGICALLY-BASED CATALYSTS FOR ENERGY APPLICATIONS

This topic is designed to stimulate innovations in biologically-based catalysts for conversions important to energy applications. The potential advantages of these catalysts for industrial scale chemical reactions are many, including chemical specificity, high yield, simplified purification, novel reactions, and reduction in waste solvents. Rapid advances in biotechnology indicate that a significant contribution can be made in this research area (see references 1-6).

Approaches are sought that bring significant innovation to the use of bio-based catalysts for high-volume, energy-related conversions leading to new sources of chemicals or fuels. Areas of interest include CO_2 reduction to fuels or chemical feedstocks, methane to methanol conversion, desulfurizing fuels, and eliminating the potential for NO_x and SO_x production from traditional fuels. Other selected conversions important to the energy economy

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will be considered, provided that the proposed research is substantially innovative and does not fall in a category of broad support by existing research programs. This topic does not cover catalysts for low-volume, high-value chemicals whose production would not substantially change the national energy picture. In addition, biocatalytic production of hydrogen will not be considered because this area is already covered by existing programs.

Grant applications should combine innovation with a clear delineation of the expected impact on an important aspect of the national energy picture, carefully defining and documenting (1) the energy advantage yielded by the proposed biotechnology; (2) the novelty in terms of the approach; (3) the realization potential of the idea; and (4) a favorable outlook for economic benefit in the near-term. The proposed research should span the proof of a concept phase to the application in an energy system. Applications oriented toward research yielding incremental improvements will not be considered. **Grant applications are sought only in the following subtopics:**

a. Extremophile Enzymes for Applied Biocatalysis—Extremophile enzymes have optimal catalytic activities under conditions of temperature, pH, salt concentration, etc. that are not normally associated with the biosystem-conditions that may be advantageous to energy-related industrial applications. Utilization of these enzymes takes advantage of the three billion years during which evolution has been designing enzyme catalysts. Grant applications are sought for the utilization of extremophile enzymes to catalyse reactions important to the national energy economy. Approaches of interest include the coupling of computational modeling to the design of biocatalysts; this approach would link structure to function, eventually leading to powerful programs for catalyst design. Grant applications that deal solely with computational aspects, however, will be declined.

b. Biomimetic Catalysis for Important Energy Applications—In biomimetic catalysis research, molecules are developed that not only mimic the active sites of enzymes but also have structural features that allow them to function under conditions beyond those of the biosystem. Grant applications are sought to develop biomimetic catalysts for energy-related conversions leading to new sources of chemicals or fuels. One challenge is to mimic the specificity of biosystem pathways while conferring chemical stability that cannot be achieved with protein catalysts. For example, using molecular imprinting, a transition state molecule or an enzyme inhibitor can be used to form an imprint in a polymer or inorganic solid matrix, conferring catalytic activity. As with subtopic 'a', grant applications are encouraged that couple computational modeling to the design and preparation stages of biomimetic catalysts. While computational aspects should support catalyst development, this should not be the major focus of the proposed research.

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* Available from law libraries or from public libraries with collections of laws and codes.

10. COMPUTATIONAL GEOSCIENCES: SUBSURFACE CHARACTERIZATION AND FLUID TRANSPORT

The DOE Office of Basic Energy Sciences Geosciences Research Program emphasizes cross-cutting studies with potential applicability to fossil fuel, renewable energy and environmental remediation areas. The program focuses on active process controls such as evolving porosity and permeability systems, fractures, fluid flow and fluid transport properties, and reactive transport to name a few. Geologic fluids include geothermal brines,

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oil and gas, ground water, and nonaqueous contaminant fluids.

This topic is limited to computational research to support analysis, prediction, and/or modeling of subsurface structures, properties, and processes based on highly efficient approaches that could be implemented by small businesses as well as large corporations/government agencies. The objectives are to improve resolution of geologic structure (matrix as well as fractures), measure contrasts in properties between geologic units, differentiate among and characterize geologic fluids, better define flow pathways in the subsurface, understand geochemical reactions/reactivity, and provide a basis for better interpretations of these structures and processes. Characterization and prediction of properties away from boreholes, between direct observation locations, fracture patterns, depositional units or subunits, and unit compartmentalization are all of major interest.

To be considered responsive, grant applications must demonstrate familiarity with current state-of-the-art methods and scientific publications in this technical area and in the area of computational modeling. Grant applications that involve minor adaptations of current or conventional methodologies will not be considered. Collaborative research and technology development with leading researchers at DOE laboratories and academic institutions is encouraged.

In addition, this topic is restricted to generic innovations for subsurface physical characterization that offer promise to a range of energy resource and environmental technologies. Other topics in this solicitation may address specific energy or environmental issues, such as oil and/or gas applications, geothermal technology, or contaminated waters, and may be more appropriate for applications that have a particular focus. Grant applications that deal with a specific energy or environmental aspect will not be considered. **All grant applications must address the following subtopic:**

a. Computational Geosciences - Subsurface Characterization: Theory, Measurement, Modeling and Interpretation—Grant applications are sought for non-conventional but promising computational approaches for characterizing subsurface features such as in situ porosity and/or permeability, depositional structure, fractures, fluid(s) characterization, and soil-fluid or rock-fluid interactions via optical imaging, geophysical imaging or other techniques. Of particular interest are computational technologies that will enable real-time monitoring, modeling, and prediction of fluid composition, fluid-rock interactions, and transport through both matrix and fractures in both the saturated and unsaturated zones. Both characterization and modeling technologies must be aimed at developing easily portable (physically or computationally) PC-based systems. Areas of interest include joint inversions/applications of multiple data sets, integration of complimentary techniques, and alternative methods of interpretation of data sets, individually or jointly. With regard to modeling, approaches must support improved data collection, analysis and interpretation.

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* Attention is drawn to research summaries dealing with geophysical imaging and geochemical reactivity and fluid transport.

** See Section 7.1.

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11. MATERIALS JOINING

Joining is a critical, enabling technology in many industrial sectors (e.g., automotive, petro-chemical, electronic and power generation) that have problems of concern to the Department of Energy. Examples range from welding two large structural components together for a nuclear or fossil power plant to making the smallest possible solder joint for high density integrated circuits. Joining is not only necessary to this wide range of technological endeavors, but the reliability of joints is often the limiting factor in the performance of the overall system. A graphic example was seen in the early 1980's, when a number of nuclear reactors came perilously close to shutting down due to intergranular stress corrosion cracks in primary water cooling piping. Not as publicly visible, but equally significant, is the fact that the absence of reliable techniques to join ceramic materials to themselves and to metals precludes the assembly of some structures (gas turbines, thermoelectric devices, etc.) that might otherwise realize the improved high-temperature performance that exists within the separate components.

Grant applications are sought only in the following subtopics. The first two subtopics deal with critical issues in welding—the welding of advanced alloys and the stability of microstructures in weldments as a function of service life. The last two subtopics are concerned with ceramic joining—developing new active metal brazing alloy compositions and comprehensive ceramic-metal joint design methodologies.

a. Welding Iron and Nickel Aluminides—Alloys of iron and nickel with the addition of 8-20 percent aluminum and certain other minor alloying elements, including boron, carbon, chromium, niobium, and zirconium, have excellent resistance to high temperature corrosive environments. Commercial application of these alloys has been hindered by difficulties encountered with conventional fabrication technology; i.e., their limited ductility restricts the use of normal techniques such as rolling, drawing, and welding. Grant applications are sought for innovative approaches to joining components of these materials, either to themselves or to dissimilar materials, to form useful structures. Candidate techniques of particular interest include friction welding, brazing, diffusion bonding, and explosive welding. Friction welding minimizes metallurgical problems since little, if any, melting occurs. Brazing aluminides to themselves, or to other metals or ceramics, requires highly aggressive fluxes or strongly reducing environments to minimize the effects of aluminum oxide formation. Diffusion bonding also requires the avoidance of oxide formation. Explosive welding joins materials with limited ductility by producing a moving wavefront which expels interfacial contaminants and establishes a metallurgical bond.

b. Embrittlement of Nickel-Based Alloy 718 Welds—Nickel-based superalloys are used extensively in many high-temperature applications in the nuclear, chemical, aerospace, and defense industries. Millions of dollars are spent each year on maintenance and inspection to keep structures and plants operating safely. These alloys, as well as others such as stainless steels, are subject to embrittlement after long-term exposure. Consequently, maintenance efforts often involve unnecessarily conservative component replacement strategies because adequate non-destructive techniques are not available for predicting remaining life. With the increasing pressure to extend component lifetimes, often beyond the original design lifetimes, improved methodologies are desired to reduce the cost of maintenance while still insuring the safety and integrity of operating facilities. Grant applications are sought to nondestructively evaluate the phase stability and transformation behavior leading to embrittlement in both welded and wrought structures under operating conditions. These behaviors must be related to degradation in properties in order to predict the remaining lifetime of components more accurately. Alloy 718, the most extensively used nickel-based superalloy, must be used for these studies. An improved understanding of embrittlement mechanisms could be readily extended to other nickel-based alloys and to other alloy systems as well.

c. Development of New Active Metal Brazing Alloys—Active metal brazing has been used to successfully join both oxide and non-oxide ceramics to themselves and to metals. However, most commercially available braze alloys have limited capabilities at elevated temperatures. Typically, the service temperature of brazed ceramic joints is limited to 500°C or less. In order to more fully realize the advantages of ceramic materials in structural applications with elevated temperatures, joints should be capable of service temperatures exceeding 800°C. Grant applications are sought for new braze alloy compositions that facilitate the formation of strong, reliable ceramic joints, while providing improved elevated temperature capability. Grant applications must address oxide (e.g. Al_2O_3) and/or non-oxide (e.g. Si_3N_4 and SiC) ceramics.

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Grant applications must describe the scientific approach in detail. For example, it has been demonstrated that the addition of active elements such as Ti to eutectic braze alloys, that normally do not wet or react with ceramics, can result in improved wetting, a requirement for any brazing process. Improved wetting behavior and adhesion have been correlated with thermodynamically favorable interfacial chemical reactions that occur between the active metal component within the braze alloy and the ceramic material. These reactions occur more rapidly at elevated temperatures, and can have deleterious effects if excessive reaction takes place. Therefore, it is critical to control the extent of reaction in prospective braze alloys at elevated temperatures. In addition, the braze alloy must remain ductile in order to accommodate residual strains within the joint, and must also possess adequate oxidation and corrosion resistance in addition to high temperature strength.

d. Ceramic-Metal Joint Design Methodologies— Engineers often seek to take advantage of the desirable characteristics of structural ceramics by making a direct substitution of a ceramic for an existing metallic component. In spite of the fact that considerable research and development has been carried out to establish successful ceramic-metal joint processing techniques, design of the joint is often put off until late in the product development process. Problems with poor joint performance are often encountered at this stage, resulting in critical delays that could have been avoided if joint design issues were considered up front. Grant applications are sought for innovative analytical or numerical methodologies for designing ceramic-metal joints in structural applications. Fundamental issues associated with predicting joint behavior must be addressed, including consideration of thermal residual stresses during fabrication, thermal and mechanical loading stresses while in service, geometry effects on stresses and failure, the role of interlayer microstructure and properties on joint performance, statistical approaches to analysis of brittle failure for predicting joint reliability, and damage accumulation concepts for predicting joint lifetimes. The initial research can focus on any actual or hypothetical joining application. However, a comprehensive methodology must ultimately be developed which can solve real-world joining problems and be translated to different materials systems and other applications.

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12. PROCESSING FOR SURFACE HARDNESS

There exists a broad range of applications for which the ability to produce an adherent, hard, thin, wear-resistant coating plays a vital role. For applications such as engine and machine components, hardened surfaces can mitigate the effects of corrosion, a major source of energy loss for the economy. Other applications include orthopedic devices, textile manufacturing components, hard disk media, micromachined sensors and actuators, optical coatings, and cutting and machining tools. This topic addresses the development and improvement of surface hardening processes which are environmentally benign and which provide flexible control over the surface structure and chemistry. **Grant applications are sought only in the following subtopics:**

a. Development of Novel Thin Film Hard Materials—Grant applications are sought to develop equipment and processes for producing novel thin layers for tribological applications. The films must exhibit high hardness, low friction and roughness, good adhesion, and the prospect of economical scale-up over large areas. Areas of interest include boron-based (>30 Gpa) and stainless steel thin films. Grant applications dealing with paints or thermal spray coatings are not of interest and will be declined.

b. Plasma Surface Modification of Materials—Grant applications are sought to develop unique plasma based surface modification techniques that are applicable to the hardening of all classes of materials (polymers, metals, ceramics). All components of a useful surface modification process (surface cleaning, ion implantation, and plasma-based thin film deposition) must be addressed and performed in a single chamber. Proposals for equipment capable of ion processing at energies from a few tens of eV to 100 keV are of particular interest.

c. Novel Characterization Techniques for Dynamic Tribological Properties of Thin Films—Currently, static tests, such as nanoindentation, are widely used to assess the film quality of hard coatings. However, dynamic tribological properties are also of interest at the nanoscale. Grant applications are sought to develop testing equipment for thin film characterization (0.01 to 1 micrometer) that evaluates fundamental dynamic behavior, such as scratch loading.

d. High-Flux, Low-Energy Ion Source—While there has been much activity in the development of large-area (200 mm diameter), low energy ion processing equipment, particularly for etching applications, there is a particular need for application of this technology to the generation of hard thin films. Grant applications are sought to develop new ion processing hardware and associated processing strategies useful for the production of tribological thin films. The process must use low energy (20-200 eV) ions and be capable of generating high uniform fluxes (at least 1 milliamp per square centimeter with a uniformity of 5 percent over a 200 mm diameter).

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13. METAL FORMING

Metal forming operations are among the most common materials processing steps in industry, both for the production of semi-finished products as well as for the manufacturing of consumer goods and military hardware. Expenditures for capital investment in plant equipment and for operation costs are enormous. In addition, these processes are extremely energy intensive. Major technological changes are on the horizon which require that significant advances be made in the science and in the technology of metal forming. **Grant**

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applications are sought only in the following subtopics:

a. Semi-solid Forming—Semi-solid forming consists of heating an alloy into the two-phase liquid-solid regime where both solid consistency and easy formability, using either casting or forging, are possible. The advantage of semi-solid casting is less shrinkage (voiding), lower casting temperatures, and, thus, less die wear. Forging can be accomplished at much lower stresses without losing the "consistency" of a solid. A necessary condition for effective semi-solid forming appears to be a spherical rather than dentritic morphology of the solid phase. Traditionally, this has been accomplished by electromagnetic stirring, an expensive process that has limited the commercial utilization of semi-solid technology. Grant applications are sought for alternative semi-solid processing techniques to reduce the cost of the spheroidization step and render the semi-solid process more viable. This opportunity may be particularly viable for aluminum alloys, many of which may be used for automotive applications. Also of interest are approaches to reduce costs associated with the production alloys which are suitable for semi-solid forming.

b. Economical Superplastic Forming—Superplasticity is usually described as high tensile ductility of a material (e.g., greater than 600 percent), leading to very favorable forming characteristics. Although superplasticity formed parts are now commercially available, particularly in the aerospace industry, widespread application has not occurred, principally due to the relatively high cost of superplastic forming. The expense is associated with: (1) the thermal and mechanical processing (TMP) necessary to produce a refined grain size that will lead to superplastic formability, and (2) the relative lengthy time required for the superplastic forming step. Part of the problem is that superplastic deformation leading to high tensile ductility is usually observed only at low strain rates (10^{-4} sec^{-1}) which preclude timely forming and reasonable costs. Grant applications are sought to bring superplastic forming into more widespread use by: (1) developing new alloys or processing techniques, suitable for superplastic forming, which would lower the costs associated with TMP, and (2) utilizing alloys (which have recently been discovered) that can be formed superplastically at relatively high rates of strain.

c. Alternative Metal Forming—Grant applications are also sought for novel, alternative metal forming practices, other that semi-solid and superplastic forming, involving powders, spays (both liquid and solid), and plasmas, as candidate processes to replace conventional metal forming practices.

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14. PROCESSING OF PERMANENT MAGNET MATERIALS

Permanent magnet materials play a significant role in a variety of technologies ranging from magnetic data storage devices to large electrical motors. The annual market for permanent magnetic materials alone is approximately $3 billion per year, and growing at a healthy rate. The discovery of new materials with improved magnetic properties will impact this market significantly. However, incremental changes are also likely to have a strong effect. The annual efficiency cost savings for a 10 percent penetration of 1 percent more efficient motors in the U.S. market alone are estimated to be $95 million. The focus of this topic is the development of improved properties in permanent magnet materials, including nonmagnetic properties which are important for many applications. **Grant applications are sought only in the following subtopics:**

a. Powder and Compact Processing—Grant applications are sought to develop improved magnetic powder

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materials and associated processing techniques for compacted powders. Areas of interest include rapid solidification (gas atomization, melt quenching, etc.); mechanical alloying; hydrogenation, disproportionation, desorption and recombination; phase diagram studies pertinent to processing; and instrumentation specifically designed to assist such processing.

b. Nonmagnetic Properties—Grant applications are sought for methods to improve critical nonmagnetic properties of permanent magnet materials (e.g., improved alloy design or microstructure). Properties of interest include corrosion resistance, mechanical properties (e.g., fracture resistance, brittleness), as well as stability of material properties at elevated temperatures.

c. Coercivity Improvements—Grant applications are being sought to develop improvements in the coercivity of permanent magnets and in the irreversible degradation of coercivity at elevated temperatures. Areas of interest include alloying and chemical substitution effects, processing to improve microstructure, the effects of impurity phases, or the synthesis of new materials.

d. Tailored Structures—Grant applications are sought for the use of processes other than traditional alloying to improve the performance of permanent magnetic materials. Such processes may include the use of thin film and superlattice methodologies, processing of nanostructured materials, or the preparation of exchange-spring structures.

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* See Section 7.1.

15. CATALYSTS FOR ADVANCED TRANSPORTATION TECHNOLOGIES

The DOE supports research and development of advanced transportation technologies that will reduce airborne emissions of pollutants from vehicles, and significantly improve urban air quality. Approaches for addressing this problem include development of proton-exchange-membrane (PEM) fuel cells and pollution control technology for heavy-duty diesel vehicles.

Fuel cells offer a potential replacement for the internal combustion engine in vehicles because they are clean, energy efficient, and fuel flexible. The PEM fuel cell is the focus of current development efforts because it is capable of high power density and faster start-ups than other fuel cells. Any hydrogen-rich material can serve as a possible fuel source for this developing technology. This includes fossil derived fuels such as natural gas, methanol, petroleum distillates, and liquid propane, or renewable sources such as ethanol or hydrogen (produced from renewable energy sources). Improved electrocatalysts are needed to facilitate the development of the PEM fuel cells for transportation applications.

Heavy-duty, diesel vehicles are an increasingly important source of NO_x which contributes to adverse health risks and plays a role in the formation of photochemical smog, acid rain, and secondary particulates. While engine and combustion improvements have substantially reduced NO_x and particulates from modern engines, the number of diesel vehicles and their highway use continues to increase. This has resulted in increasingly stringent Federal and State standards for NO_x and particulate emissions. Therefore, improved catalytic processes are needed to reduce NO_x and particulate emissions from diesel engines. **Grant applications are sought in only the following subtopics:**

a. Contamination-Tolerant Anode Catalysts for PEM Fuel Cells—To take advantage of the existing fuel infrastructure, and thus facilitate the introduction of fuel cells into the transportation sector, the DOE is currently exploring the use of reformed liquid fuels. Reformed fuels, however, contain low levels of carbon monoxide (CO) which poisons the platinum anode catalyst. Grant applications are sought to develop anode catalysts that are able to tolerate at least 500 ppm CO while sustaining stable fuel cell performance (voltage loss less than 20 mV at a current density of 0.5 A/cm^2). Approaches must use

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either platinum alloy or nonprecious metal catalysts. The electrode material must be stable in the acidic medium of a perfluorinated sulfonic acid polymer electrolyte (roughly equivalent to 0.5 molar sulfuric acid) and have an adequate exchange current density for the hydrogen oxidation reaction (at least 10^{-3} A/cm^2 of catalyst surface area). Applicants are encouraged to use in situ characterization methods to establish relationships between surface structure, composition, and catalytic performance, as well as to demonstrate performance of model catalyst/ionomer interfacial systems.

b. Methanol Oxidation Catalysts for Direct-Methanol Fuel Cells—Direct methanol fuel cells (DMFCs) eliminate the need for an external reformer, reducing the fuel cell system weight and cost. However, the rate of methanol oxidation is several orders of magnitude lower than that of hydrogen on a platinum catalyst, and oxidation products other than water and carbon dioxide have been observed in some cases. Grant applications are sought to develop electrocatalysts for DMFCs. Requirements for electrode catalysts include stability in an acidic medium (equivalent to 0.5 molar sulfuric acid) or in aqueous carbonate, and an activity per unit electrode area for the methanol electro-oxidation reaction that is superior to that of platinum ruthenium anode electrocatalysts under the same cell operation conditions. Applicants are encouraged to use in situ characterization methods to establish the relationships between surface structure, composition, and catalytic performance, as well as to demonstrate the performance of model catalyst/ionomer interfacial systems.

c. Catalysts for Fuel Processors—Improvements in hydrocarbon fuel reforming catalysts are necessary to utilize the existing fuel infrastructure in PEM fuel cells for transportation. Grant applications are sought for improved catalysts for partial oxidation and autothermal reforming of hydrocarbon fuels. Key issues to be addressed are (1) cleaving the C-C and C-H bonds without the formation of C=C bonds which lead to coke formation; (2) suppressing the formation of methane which is difficult to reform; (3) reforming aromatics, polynuclear aromatic, and cyclic hydrocarbons; (4) high activity at low temperatures, and (5) tolerance to sulfur. Grant applications will also be considered that address the development of catalysts to reduce the level of CO emitted from the fuel processor to less than 2 percent.

d. Non-Thermal Plasma Catalytic Processes for NO_x and Particulate Reduction from Heavy Vehicle Exhaust—The DOE is supporting the research and development of catalytic processes to reduce NO_x and particulate emissions from diesel engines. Conventional technologies such as three-way catalysts do not effectively reduce NO_x in the high-oxygen exhaust of a diesel engine. One novel approach is the use of plasma-assisted catalyst systems to selectively reduce NO_x and oxidize particulates and hydrocarbons. This approach involves the generation of a non-thermal plasma that produces a highly energetic and selective catalytic surface for NO_x and particulate removal. Grant applications are sought to develop plasma assisted catalysts that are capable of reducing NO_x under high-oxygen exhaust conditions. The research and development should be targeted toward understanding the fundamental plasma/catalyst chemistry (kinetics, thermodynamics, and mechanisms) and improving the system efficiency. Issues to be addressed are simultaneous NO_x and particulate removal, energy requirements, operating temperature, and durability and reliability of the catalyst. Proof-of-concept for a catalytic system capable of 90 percent NO_x removal and 90 percent particulate removal must be established during Phase I.

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16. CHARACTERIZATION OF ELECTROCHEMICAL INTERFACES IN ENERGY STORAGE AND CONVERSION PROCESSES

Superior technology in energy storage and conversion processes, such as batteries and fuel cells, result from a fundamental understanding of the electrochemical processes involved. In large part, these electrochemical processes occur at the interface between the electrolyte and the electrode, on a microscopic level that is difficult to observe and to measure. Experimental insight into these electrochemical processes is largely limited to information obtained within a framework of macroscopic thermodynamic and kinetic concepts, a limitation that retards progress in battery and fuel cell technologies. It also constrains the design of commercial electrochemical power source systems to empirical methods, resulting in loss of process efficiency, product yield, and flexibility of product design. An opportunity exists to examine these interfacial processes and ascertain detailed features of electrochemical reactions, participating chemical species, and interfacial structure with a precision heretofore not possible.

Interfacial characterization technologies are needed for the study of energy storage and conversion processes in batteries, capacitors, and fuel cells. Opportunities exist in four areas of research: interfacial chemical composition, interfacial structure, *in situ* methods for characterizing interfaces, and characterization of processes in the boundary layer. Special emphasis should be placed on characterizing these interfacial processes and structures with greater chemical detail and with resolution approaching atomic scales. **Grant applications are sought only in the following subtopics:**

a. Identification of Participants in Electrode Reactions—A knowledge of the individual chemical participants is indispensable to achieving an understanding of electrode processes, such as the electrooxidation of methanol. Grant applications are sought to develop methods to identify the participants in electrode/electrolyte reactions with high chemical specificity. Areas of interest include: (1) vibrational spectroscopy, which among established techniques for chemical identification, offers the best opportunity for improvement; (2) mass spectrometry, which has a demonstrated, but largely undeveloped, general applicability to the characterization of intermediates and products in electrochemical processes; and (3) magnetic resonance techniques, which apart from electron spin resonance, have not yet been applied to electrochemical processes at the interface, but recent dramatic improvements in sensitivity suggest their applicability to the electrochemistry of energy storage and conversion processes.

b. Fine Spatial Characterization of Interfacial Structures—Electrode reactions often involve kinetic steps that occur in three-dimensional structures, such as active catalytic sites, nucleation centers, and adsorbed layers. These structures are rarely known. Grant applications are sought to apply x-ray methods, particularly diffraction and extended x-ray absorption fine structure (EXAFS), to achieve a markedly improved capability for spatial characterization of interfaces. In addition, grant applications are sought to develop newer methods for characterizing interfacial structures, such as scanning tunneling microscopy and nonlinear optical processes.

c. Correlations of *In Situ* and *Ex Situ* Observations—*Ex-situ* characterization methods of surface science have already been established within an electrochemical context, because they can provide structural definition on fine distance scales. Such characterization includes the atomic composition of a surface and vibrational spectroscopy of adsorbates. Grant applications are sought to develop methods for *in situ* characterization and to clarify the relationship between *ex situ* and *in situ* measurements. Possible experimental approaches that can be employed in both environments include vibrational spectroscopy, ellipsometry, radiochemical measurements, and x-ray methods.

d. Improved Characterization of Boundary Layers—The boundary layer adjacent to an electrochemical interface is the extended zone through which species must be transported to a site of electron transfer. Intercalation electrodes and separators, which have fixed-geometry channels for transport or mediated reaction through natural or synthetic surface-attached networks of charged polymers, are prominent examples in which dynamic electrochemical processes in a boundary layer may control an overall rate. Grant applications are sought to develop techniques that can be used for both understanding the behavior and enhancing the performance of these boundary layer processes. Approaches should include structure-sensitive techniques that are valid in both *in situ* and *ex situ* circumstances.

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* See Section 7.1.

17. HIGH TEMPERATURE SUPERCONDUCTIVITY FOR ENERGY APPLICATIONS

Superconductivity is the ability of current to flow through electrical wires in perfect order, without the random motions that normally cause resistance losses. A tremendous amount of energy, several percent of all electricity generated, is needed to "push" electrical current against the resistance of conventional copper or aluminum wires. Scientists have known since the discovery of superconductivity in 1911 that this loss does not occur in certain special materials that can carry "supercurrents," large electrical currents flowing without resistance loss. Unfortunately, the thousands of such materials discovered before 1986 needed to be cooled to temperatures found naturally only in the coldest regions of outer space. The difficulty of artificially creating temperatures near this absolute zero temperature prevented widespread use of superconductivity.

The situation changed dramatically with Nobel prize-winning discoveries of high-temperature superconductivity (HTS) in the late 1980s. HTS exists in a new class of ceramic materials able to carry supercurrents at temperatures attainable with established industrial refrigeration practices. These discoveries offer tremendous opportunity for more efficient electrical power plants; higher capacity power cables; environmentally friendly transformers; and more powerful motors.

The key to capitalizing on these many opportunities is developing high-performance, low-cost HTS wires. The ceramic nature of HTS materials originally made them unlikely candidates for use in electrical wires due to the brittle, granular characteristics of ceramics in general and HTS materials in particular. Entirely new processing methods were needed to allow intergranular electrical current flow, and to provide HTS wires with the flexibility and strength needed for practical use. Steady progress has been made, and kilometer lengths of HTS wire can now be manufactured by several companies around the world. Also, performance breakthroughs in short sample lengths have recently been achieved in "coated conductors" - superconducting coatings on specially prepared metal strips that potentially can lead to a second generation of HTS wires with favorable cost and performance characteristics.

Innovative solutions to HTS wire cost and performance barriers are still needed. For example, less than 20 percent of the wire cross section carries current in the HTS wires now being manufactured. Improvement here could both raise performance and lower cost. Research on the "coated conductor" approach has begun only recently and innovative approaches are needed on preparing the underlying metal strip, developing a suitable coating process for the superconductor, and scaling up to wire manufacturing. Meanwhile, innovative uses are needed for the wires now being manufactured to accelerate their commercial use.

A world-wide market of several billion dollars per year for superconductivity products has been predicted for the year 2000, with wire-using products comprising the largest market share. Continued innovation is needed to overcome the existing technical and economic barriers to exploiting this potential. Incremental advances to current HTS technology will not be considered. **Grant applications are sought only in the following subtopics:**

a. HTS Wire and Coil Manufacture—Grant applications are sought for the development of innovative processes and process quality management technologies for manufacturing HTS wires that will: (1) lead to manufacturing costs comparable to that of low temperature superconducting wire (presently around

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$30/KAmp-meter for Nb_3Sn composite conductors), or (2) improve HTS wire performance in areas such as uniformity of long wires, current carrying ability (above 500 A/sq mm), operating temperature ability, operating magnetic field ability, flexibility, and durability. This also includes improvements in splices between HTS wires and between HTS and normal wires. Grant applications are also sought for the development of innovative HTS coil manufacturing processes and process quality management technologies that will lower costs or improve HTS coil performance in areas such as durability, operating magnetic field ability, and efficient alternating current operation.

b. HTS Electrical Device Development—Grant applications are sought for development of HTS electrical devices, using presently available HTS wires, that can improve the efficiency and economics of electrical generation, delivery, or use. These may be innovative designs for familiar electrical devices such as generators and motors, or proposed new inventions which are enabled by HTS. Grant applications for device/associated coil protection measures are also sought.

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18. HIGH PERFORMANCE COMPUTING CONCEPTS AND INFORMATION INFRASTRUCTURE FOR THE NATIONAL INFORMATION INITIATIVE

The DOE supports research in several areas of mathematical modeling, advanced computing, and high-speed networking as a result of its participation in the Federal, interagency High Performance Computing and Communications (HPCC) and National Information Infrastructure (NII) Initiatives. With regard to the HPCC program, the Department is funding research in mathematical modeling of physical phenomena, algorithm development for massively parallel and distributed computing environments, software tools and advanced visualization techniques, and user interfaces for high performance computers of the future. With regard to the NII program, the Department is funding research in communications and networking technologies that support distributed, collaborative research and digital communication. In order to further and enhance the Department's role in the HPCC and NII programs, **grant applications are sought only in the following subtopics:**

a. High Performance Algorithms—High performance computers will continue to employ arrays of processing units operating in parallel to achieve high computational speeds and efficient management of the resulting large datasets. In order to take full advantage of this computational power, robust and efficient computational and visualization algorithms must be developed that are driven by genuine applications to scientific and engineering problems of relevance to the Department. Grant applications are sought for the development and implementation of new numerical methods and algorithms that can exploit current and planned parallel and distributed architectures in solving problems of importance to the Department's mission, as outlined in the references below (especially references 4 and 10). Applicants are expected to be thoroughly familiar with the current state-of-the-art in numerical methods and algorithm development.

b. Advanced Computing Concepts—The high-performance architectures and networks in current and planned use require development and implementation of advanced software tools and systems for their effective utilization. Efficient software environments for development, testing, maintenance, evolution, and tuning of high-performance applications are needed. Grant applications are sought for research and development, and implementation leading to a commercially viable product, in one or more of the following areas: globally optimizing compilers, parallelizing compilers, portable mixed-language programming; debugging and performance tuning tools that work with highly optimized programs and relate results to source code; portable parallel libraries and interfaces supporting high-performance applications and parallel input-output technology; widely distributed high-performance computing; technology for interoperable tools and high capability data visualization. Applicants are expected to be thoroughly familiar with current commercial software, and with ongoing laboratory and academic research.

c. Collaborative, Database, and Security Technologies Based on Wide Area Networks (WAN)—Advances in high-performance networks and communication, combined with the enhanced sophistication of laboratory applications, have accelerated the need for fast, distributed, interoperable, and scalable technologies for collaboration and data management. Collaborative tools and systems that support shared telepresence in the context of laboratory missions is required. Enabling software for storing, retrieving, analyzing, and visualizing large volumes of data in easy-to-use ways is necessary. These require differing levels of authentication and security services, which must be made available in modular ways. Grant applications are sought for research and development, and implementation leading to a commercially viable product, in one or more of the following areas: Internet-based, cross-platform conferencing technologies, including shared video, audio, whiteboard, and meeting logs which are configurable for a variety of meeting protocols; network-based tools for remote and collaborative control of experimental instruments, including remote graphical display, interactive steering, and logging; software for distributed management of large scientific databases; cost-effective software and environments for immersive visualization and virtual reality applications; interoperable authentication and security mechanisms that can be selectively incorporated into all of the preceding technologies. Applicants are expected to be thoroughly familiar with current commercial offerings, and with ongoing laboratory and academic research.

d. WAN Based Technologies for Energy Demand and Supply Management—Electric and power utilities are deploying telecommunications technologies to

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support their principal business of providing energy to their customers. However, the evolving nature of the corporate utility business demands the development of novel distributed network technologies to enhance the existing capabilities of utilities in the area of real-time energy demand and supply management. The technologies and infrastructures that support energy utility consumers and providers may be leveraged to accommodate other utilities and service providers. Grant applications are sought for the development and implementation of both wide area based and distributed network tools and protocols that enable energy utilities to improve efficiency, conservation, billing, and customer service. Applicants are expected to demonstrate familiarity with the current state-of-the-art in these areas, especially with regard to how the consumer interfaces and connects to both the utility and the NII.

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World Wide Web Information:

1. Department of Energy, Office of Energy Research
   http://www.er.doe.gov
2. National Coordination Office for High Performance Computing and Coomunications
   http://www.hpcc.gov

* See Section 7.1.

** Available from the National Coordination Office for Computing, Information and Communications (formerly National Coordination Office for High Performance Computing & Communications), 4201 Wilson Boulevard, Suite 665, Arlington, VA 22230. Telephone 703-306-HPCC. Fax 703-306-4727.

19. INTELLIGENT CONTROL OF ENERGY TECHNOLOGIES USING CHAOS THEORY AND OTHER TECHNIQUES

The effectiveness and efficiency of many energy-related technologies could be improved through the implementation of advanced intelligent controls. Technologies that could benefit from such controls include fluidized-bed contacting, combustion, precision machining, and waste processing. Fluidized-bed contacting is one of the most widely used chemical processes and is an essential step in the catalytic cracking of petroleum. Combustion is a major consumer of fossil fuels and a primary source of greenhouse gases and nitrogen oxide emissions. Precision machining is a very important manufacturing step in the production of critical energy-related compounds, such as automotive engine blocks. Waste processing, including reclamation of valuable materials from hazardous and non-hazardous wastes, is essential for ensuring the environmental acceptability of energy production and manufacturing technologies. Even relatively small efficiency improvements in any of the above could translate into multi-million dollar savings and major reductions in negative environmental impact.

In some of these systems, key process components exhibit irregular, temporal fluctuations. If these fluctuations are caused by a small number of dominant

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non-linearities, they may be manifestations of low-dimensional chaos. The implementation of chaos control concepts may make it possible to significantly reduce or modulate fluctuation intensity, thereby greatly improving energy efficiency, increasing production rate, and reducing pollutant emissions. Subtopics 'a', 'b', and 'c' below seek applications of chaos control to fluidized beds, combustion, and precision machining, respectively. For these subtopics, grant applications should address the following issues: (1) use of time series embedding techniques to verify and characterize low-dimensional chaos in experimental laboratory examples of key processes; (2) determination of mathematical models for the global dynamics of relevant processes and computer implementation and investigation of chaos control on the mathematical models; (3) implementation and investigation of chaos control on experimental model systems in the laboratory; and (4) translation of the new techniques to industrial practice. Depending on circumstances, it may be possible to bypass issue (2) and rely purely on analysis of experimental data to develop and implement chaos control strategies.

Regarding waste processing, a vital need exists for cost-effective and environmentally compatible recycling processes for the economical reclaiming of valuable substances or materials from hazardous and non-hazardous wastes. However, many potentially attractive processes available for recycling applications are currently discounted due to high costs, long cycle times, high energy use, marginal efficiencies, or unacceptable impact on the environment. Incorporating intelligent technologies into known processes or developing novel intelligent processes could overcome these drawbacks. For example, the automated segregation and handling of waste using intelligent processing systems and sensing technologies could reduce cycle times while minimizing handling requirements. Subtopic 'd' addresses thermal plasma processing, a technique that can dissociate and separate materials in a waste processing stream. **Grant applications are sought only in the following subtopics:**

a. Application of Chaos Control to Fluidized-Bed Reactors—Fluidized beds are a cross-cutting technology heavily affected by temporal fluctuations. Uses for fluidized beds cover an extremely wide range including chemical reactors, mixing or drying solids, heat exchange between gases and solids, solids classification or size modification, and low-grade fuels combustion. Grant applications are sought on the use of chaos control to enhance or diminish large pressure fluctuations (a phenomenon known as slugging) in fluidized-bed reactors. Control systems that can be retrofit to existing fluidized beds with minimal equipment modifications are of greatest interest. Such control would be of direct benefit to a wide range of chemical, fossil-fuel processing, and waste-treatment industries. In these industries, slugging is often a major cause of low conversion, rate restriction, and maintenance downtime for fluidized-bed reactors and combustors. For example, many such reactors and combustors (which can cost from $10 to $100 million to construct) have internal heat exchanger tubes that can be severely eroded by slugging particles. Reduction or elimination of slugging also enables higher conversion of chemical reactants and higher heat transfer.

It is occasionally desirable to enhance or initiate slugging in order to destroy unwanted solid agglomerates that can form in such reactors. Thus optimal slugging control would permit both diminishment and enhancement of slugging at the operator's discretion. Development of such a capability would have significant commercial impact.

b. Application of Chaos Control to Combustion—Grant applications are sought on the use of chaos control to reduce cyclic combustion variation in internal combustion engines and in pulsed combustion. Reduction of cyclic variation is important for increased efficiency and reduced NO_x emissions.

In internal combustion engines, cyclic variations are governed to a large extent by the interaction of stochastic (high-dimensional) and nonlinear deterministic (low-dimensional) processes in individual cylinders. The variations are enhanced by fuel-lean operation (i.e., operating with more air than is needed to burn the fuel) which has been implemented to reduce NO_x emissions. These variations impose a lower limit on the fuel-to-air ratio that could be extended to even leaner values if the variation amplitude could be reduced. Fuel efficiency increases of up to 12 percent and NO_x reductions of 10-50 percent are theoretically possible, if the operating fuel/air ratio can be decreased closer to the intrinsic flammability limit. Grant applications are sought on the use of chaos control concepts to develop accurate models for the interaction of these processes and to determine feedback control strategies that extend the lean operating limit and achieve significant performance improvements.

Pulsed combustion is a paradigm for many types of combustion-generated oscillations, such as oscillations in gas turbine combustors and pulverized coal boilers.

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Typically, such oscillations arise as a result of a highly non-linear, dynamic coupling between the flame and acoustic or flow modes downstream. These oscillations in turn cause spatial and temporal variations in temperature and concentration that can increase emissions such as NO_x and decrease fuel efficiency. Chaos control concepts can provide a framework for understanding the fundamental structure of such oscillations and identifying methods whereby they can be tailored to a particular context. For example, in gas turbines, one of the principal technical needs in achieving 65 percent NO_x reduction and a 15 percent increase in energy efficiency is to reduce greatly the oscillation magnitude. This objective might be met by "destabilizing" the combustion to enhance chaos and produce a more broadband frequency spectrum. Grant applications are sought on the use of chaos control to "smooth out" or "shape" combustion oscillations, since this is of major importance in the development of low NO_x burners and gas turbines.

c. Application of Chaos Control to Precision Machining—Tool chatter is a phenomenon characterized by large-amplitude oscillations of the cutting tool which severely degrade the quality of the resulting metal product. Typically, tool chatter occurs as the cutting depth and/or rate are increased to a critical level. Thus, the onset of tool chatter limits maximum production rate and component quality at maximum production. Furthermore, the onset of chatter during any part of the machining process often requires the rejection or re-machining of the component. The resulting negative impact on manufacturing energy efficiency and component performance in its end use (e.g., automobile engines) can be severe.

Grant applications are sought on the use of chaos control to inhibit tool chatter. Experiments have confirmed that normal, non-chatter tool oscillations are typically chaotic, and the onset of tool chatter is characterized by a reduction of chaos and the initiation of large-amplitude periodic (non-chaotic) oscillations. In this case, it is expected that an optimum control strategy would stimulate chaotic tool motion at the expense of the periodic motion, a concept sometimes referred to as "anti-control." Such control would convert the large-amplitude periodic motions concentrated in a small frequency range into smaller motions spread out over a wide range of frequencies. The desired result would be an increase in the maximum cutting rate for a given quality level or an increase in the quality at maximum production rate. This technology is expected to have wide-ranging applications in many manufacturing processes including automobiles, precision optical instruments, and the production of high-speed rotating machinery such as pumps, compressors, and turbines.

d. Novel Plasma Processing of Waste—An emerging approach to waste treatment involves thermal plasma processing. This technique can dissociate materials so that toxic or radioactive elements or compounds are isolated from waste processing streams. This approach could also be used to separate desirable substances in sufficient volumes for reuse as feedstock, thereby conserving nonrenewable resources. Grant applications are sought to apply intelligent technologies to plasma processes, enhancing the likelihood that this approach could become commercially viable. For example, modeling and simulation tools could be developed to gain a better understanding of the chemical reactions of waste under plasma conditions; in turn, this understanding could be combined with intelligent sensing and process optimization to efficiently separate materials in a waste stream. Clear indications of the potential benefits of the proposed intelligent methods must be described in the grant application.

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20. ADVANCED SENSORS, MATERIALS, AND CONTROL SYSTEMS FOR HARSH INDUSTRIAL AND AGRICULTURAL ENVIRONMENTS

Many energy-intensive and/or waste producing industrial and agricultural applications and processes are not presently controllable in real-time due to a lack of robust sensors or control systems. These processes present challenging measurement environments which often include high temperatures, corrosives, moisture, dust, fumes, and extreme pressures. Furthermore, in the absence of robust sensors and transducers, many industrial and agricultural applications and processes do not benefit from the productivity enhancement realized with automated control systems. The opportunity exists to impact industrial and agricultural applications and processes through research on identified sensor needs as well control strategies which leverage existing novel approaches to harsh environment measurements.

Innovative concepts are needed in the areas of advanced sensors, materials which ruggedize existing sensors, and control systems. These concepts should lead to reduced energy consumption, waste elimination, and increased industrial productivity. Grant applications that deal predominantly with development will be declined.

Proposers are expected to be thoroughly familiar with the state-of-the-art in relevant sensor technology and control system development. Reasonable understanding of at least one potential industrial or agricultural application should also be demonstrated. Collaboration with technical experts and potential end-users is encouraged. **Grant applications are sought only in the following subtopics:**

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a. Advanced Sensors—Grant applications are sought to apply emerging transducer technologies to the development of robust, on-line sensor systems (transducers and associated hardware) that are capable of operating in harsh manufacturing or agricultural applications and environments. Proposed sensor concepts must possess novel signal acquisition, signal processing, and/or data reduction techniques. Grant applications must have a significant research component aimed at mitigating one or more clearly identified technical barrier(s) to the widespread adoption of the technology. Novel sensor concepts, new measurement schema, and advanced signal processing methodologies are of particular interest.

b. Advanced Materials—Grant applications are sought for the development of materials with unique physical properties which provide through these unique physical properties, the opportunity to deploy recently developed or emerging sensor technologies in close or immediate proximity to harsh measurement environments. Applications must demonstrate how the advanced materials will facilitate the use of transducers in challenging environments such as furnaces, boilers, distillation columns, evaporators, harvesting machinery, food processing, lime or phosphorus calcining or other energy-intensive and harsh industrial or agricultural applications. Grant applications must pertain to the identification of new materials or compounds which provide ruggedization to existing or emerging transducers or to application methodologies which facilitate new and economical ways of using existing materials with desirable physical properties.

c. Intelligent Control Systems—Grant applications are sought for new concepts which, when coupled with total process and product quality control models, can be used to develop energy-related intelligent control systems for energy-intensive industrial or agricultural applications and processes that have lacked productivity improvement through real-time control. Research efforts should lead to significant energy savings, environmental enhancement, and productivity improvements if complemented by advanced sensor developments. Research areas of interest include hierarchical control systems, energy-related applications of artificial intelligence, development of knowledge-based expert systems, and advanced implementation of total process and product quality control models. Applications limited to presently available sensors will be declined.

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21. SYSTEMS AND PRODUCTS FOR PASSIVE SOLAR BUILDING APPLICATIONS

Passive solar buildings make strategic use of natural heating, cooling, lighting, ventilation, and other natural cooling strategies in combination with energy efficiency features to significantly reduce the need for conventional energy sources. Advances in building materials and construction techniques, driven by energy, environmental, and other market concerns hold the promise for further dramatic improvements in the thermal and environmental performance of buildings. Examples of recent systems/product advances include structural insulated panels (SIPs) for the building envelope, high performance glazings for windows, and recyclable materials for various building applications.

To fully realize the benefits of these advances, appropriate design solutions and construction techniques must be implemented within the context of the "whole building." An understanding of the trade-offs involved requires the use of models and design tools that can adequately characterize these systems -- particularly their interactions and impacts on overall building performance. Therefore, it is also important that adequate data be available to provide confidence in the design tools and the performance projections. **Grant applications are sought only in the following subtopics:**

a. Structural Insulated Roof Panels with Integrated Daylighting Systems—SIPs are gaining market share for numerous building envelope applications, including roofs of residential and commercial buildings. Unlike conventionally insulated truss roofs, SIPs constitute a solid no-cavity structural element that is ideal for cathedral ceiling roofs in residential buildings and low-slope/no-slope roofs in commercial buildings. The challenge is to develop integrated SIP/daylighting systems that provide daylight and resolve the leakage problem commonly associated with roof daylighting components.

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Grant applications are sought to design and develop products or systems to enable daylighting in buildings that incorporate SIP roof systems. Products/systems should specifically be applicable to SIP panels, and should be integrated with the unique design, production, and assembly characteristics of SIPs. These include SIPs with expanded polystyrene, extruded polystyrene, and urethane (foamed-in-place or pre-formed) core materials, and with oriented strandboard or other structural skin materials. The roof aperture/SIP system should show innovation in design, in particular, the ability to provide high quality daylighting without significantly increasing building heating or cooling requirements. Designs should provide heating contributions when desired and cooling load avoidance when necessary. Designs should also be suited to building renovations as well as to new construction.

b. Products/Systems for Passive Solar Buildings Made of Recycled Materials—The DOE mission encompasses the energy and environmental benefits of such sustainability issues as the recycling of products and materials. To this end, grant applications are sought for products and systems that are elements of passive solar buildings and made of predominantly (more than 50 percent) recycled materials. The building elements can include fenestration, structure, controls, distribution systems, and the like. They should also contribute to solar gain, thermal storage, daylighting, natural ventilation, and other passive solar energy performance attributes. At a minimum, a passive solar building with the recycled materials should perform on par with a passive solar building with conventional materials. The concepts can include one or more of these elements as long as their recycled content is confirmed.

Grant applications must address new products/systems where the recycled content is the essential element of the passive solar strategy (for example, recycled gypsum wall board used as fill in interior partition walls for added thermal storage capacity). Applications must address the effectiveness of the material for its particular application, the best formulation for the material (e.g., crushed, pulverized, etc.), how it would be produced, and what construction practices/equipment requirements would be needed. Grant applications that address the numerous recycled products already in evidence in the passive solar industry (such as autoclaved cellular concrete masonry, recycled-plastic water walls, steel structural frames and windows, and cellulose insulation) will be declined.

c. Integrated Window/Light Shelf Systems—Light shelves are used to improve daylighting distribution in occupied spaces and to reduce the glare. Light shelves direct a portion of the sunlight, which would normally illuminate a space in close proximity to the window, to interior spaces. This results in a greater opportunity to use natural light in place of electric light, as well as improves the occupant's visual comfort. Light shelves typically are architectural elements that are integral to the building facade, and can be fixed or adjustable (louver-like). As a result, light shelves are more commonly specified in new construction. Grant applications are sought for the design and development of integrated window/light shelf systems/products that could be readily used in the renovation market as well as new construction. Holographic films on the window glazing, which have been investigated for this purpose, are not considered appropriate for this solicitation.

The product/system should be designed with broad applicability in mind, accounting for variations in commercial building fenestration requirements. This is particularly important for renovation applications. It should be capable of directing light efficiently over a broad range of solar/climate conditions, providing uniform light distribution and no glare. Multi-purpose designs that enhance daylighting, winter heat capture, and summer solar load avoidance are encouraged.

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22. LIQUID NATURAL GAS STORAGE FOR HEAVY VEHICLES

The energy demand of heavy vehicles used for commercial transport is growing, and by the year 2010 is projected to equal the energy demand of the automobile. In recognition of this, the DOE has a research and development mission to develop, by the year 2004, enabling technologies to achieve fuel flexibility, ultra-low emissions, and 10-mpg fuel efficiency in class 7 and 8 trucks. The strategy focuses on improving efficiency and alternative fuel capability to the diesel engine. Continual improvement of diesel engine efficiency and fuel-flexibility is a real and achievable strategy that can maintain the vitality of the trucking industry into the foreseeable future.

To achieve the goal of 10-mpg fuel efficiency in class 7 and 8 trucks, advanced diesel engine research is underway to develop a 55 percent thermally efficient engine for both diesel and alternative fuels, including natural gas. These lean burning, low emission natural gas engines can use either medium pressure (500 psi) port or high pressure (3000 psi) cylinder fuel injection systems. The trucking industry's fuel storage system of choice for natural gas is liquid natural gas (LNG), but current LNG storage tanks have pressure ratings less than 100 psi, which is lower than the fuel pressure required by the engine. Various solutions to this problem have been discussed (see ref. 1, 2, 5, and 7), but no agreement has been reached. R&D is needed to develop cost effective, safe, energy efficient, and reliable LNG storage systems for these new state-of-the-art natural gas fueled diesel engines. Specifically, DOE has interest in supporting work on cryogenic pressure vessels and LNG system hardware.

a. LNG Storage Tanks—Grant applications are sought for fuel tank designs, materials, and construction methods for medium pressure (500 psi) and high pressure (3000 psi) cryogenic storage vessels for LNG. Low pressure tank designs (less than 100 psi) are also sought if they include an on-board cryogenic pump for high pressure fuel delivery. Designs should be based on materials studies and laboratory experiments and should also address trade-offs. Tanks must have a 100-gallon capacity, have a 3.5 safety factor, and be in accordance with Department of Transportation and ASME standards. Variances from these standards must be explained. Selection criteria are cost effectiveness, measures of tank performance, structural integrity, material recyclability and conformable tank shape. Applicants must also address the relationship between the tank's structural integrity and heat leak rate. Phase I can be a modeling study with laboratory proof-of-concept being performed in Phase II.

b. LNG Component Hardware Development—Grant applications are sought for significant improvements in the hardware components of LNG storage systems for heavy vehicles. Components of interest are cryogenic pumps, fuel level gauges, and instrumentation for in-situ natural gas composition measurements, liquid/vapor pressure control, and vent gas management. Applicants must clearly identify the improvement(s) over practices/components currently used for on-board LNG fuel storage.

c. LNG Systems Analysis—Grant applications are invited for the design and systems analysis of the integrated process concerning the delivery of high pressure natural gas fuel (500 to 3000 psi) to direct injection engines. The analysis must address energy efficiency, cost, and performance for designs capable of supplying high pressure fuel. At a minimum, this study should include high pressure cryogenic tanks as well as conventional 100 psi LNG tanks with a liquid pump. In addition, all designs must account for the control and recovery of boil-off gases.

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* Performed for the Gas Research Institute by the Southwest Research Institute, Engine, Fuel & Vehicle Research Division, San Antonio, Texas.

** See Section 7.1.

23. 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, electronic systems, and engine combustion systems for future highway vehicles. These technologies could reduce the drivetrain 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, Power Electronic Building Blocks (PEBBs) to increase the overall power efficiency, and improvements in proton-exchange-membrane (PEM) fuel cells. **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 promises to provide high electric propulsion efficiency over a wide power and speed range. Improvements in the motor's cost and power density are needed to meet PNGV goals, which, for a reference 100 Kw motor, are $4/Kw and 2 Kw/kg, respectively. Grant applications are sought to develop advanced AC induction motor technology for electric and hybrid electric powertrains that can meet these goals. 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 must 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. Power Electronic Building Blocks for Hybrid Electric Vehicles—Among advanced semiconductor power technologies, PEBBs have potential application as intelligent power modules in electric and hybrid electric passenger vehicles. Grant applications are sought to develop PEBBs· technologies to increase the overall efficiency of hybrid electric vehicles. Areas of interest include power devices, isolators, power supplies, firm-ware protection controls, capacitance, inductance, and device software programmability. The software enables the devices to drive motors, actuators, or supply AC power. Devices must operate in harsh environments that include high temperature, moisture, vibration, and electromagnetic interference. Grant applications must quantify: (1) the development risks inherented in scaling up current/power density for devices, components, or modules; (2) factors involved in the integration of components into modules; and (3) the cost of devices in production volumes of 20,000 to 100,000 per year. Research efforts are expected to involve multi-disciplinary teams of scientists and engineers.

c. Bipolar Plates for Fuel Cells—Fuel cells offer a potential replacement for the internal combustion engine in vehicles because they are clean, energy efficient, and fuel flexible. The PEM fuel cell is the focus of current development efforts because it is capable of high power density and faster start-ups than other fuel cells. The current cost of PEM fuel cells is too high for automotive applications, in large part due to the high cost of bipolar separator plates, which are currently made of machined graphite. The high cost of machined graphite plates is primarily based on the high cost of the manufacturing process. Cost of separator plates may be reduced by decreasing the thickness of the graphite plate, by developing low-cost manufacturing processes for the graphite plate, or by developing alternative separator plate materials or coatings. Grant applications are sought for innovative research and development of low-cost, lightweight separator plates for PEM fuel cells. Grant applications must address cost, weight and volume, manufacturability, electronic conductivity, gas permeability (porosity), corrosion, chemical compatibility with the electrode and electrolyte materials, durability, and thermal and water management. Materials and process development should be emphasized during

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Phase I with follow on testing in a PEM fuel cell stack during Phase II.

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24. ADVANCED COAL TECHNOLOGY

Although coal is our most abundant and inexpensive fossil fuel, the release of clean energy from coal requires the solution of many problems in processing, transport, and conversion. The results of novel approaches and innovative research could contribute to greater utilization of our coal resources. **Grant applications are sought only in the following subtopics:**

a. Coal Treatment Processes—Coal treatment processes are needed (1) to modify coal in order to prepare a fuel appropriate to particular applications and (2) to recover the millions of tons of coal fines (minus 28 mesh) which are being disposed of as waste material. Coal preparation processes include the removal of ash-producing minerals such as pyrite, trace elements, sulfur, and nitrogen through physical, chemical, biological, or combined methods. New process concepts, or improvements in existing processes, can enhance beneficiation technologies and/or the handling and marketability of coal. Grant applications are sought to develop innovative coal preparation processes or to advance existing coal preparation processes such as comminution, surface- or density-based cleaning, dewatering/drying for either low or high rank coals, and reconstitution.

Grant applications are also sought for novel approaches to recover waste coal fines, currently impounded or being generated from coal preparation processing plants, and either processing them into a singular fuel form (e.g., pellets, slurry, etc.) or combining them with other waste materials (e.g., sludge, fibers, biomass, etc.) to provide a uniform, marketable product suitable for utility use. Environmental and economic benefits that may be obtained from recovering these coal fines include limiting the amount of coal waste sent to storage ponds and providing a potentially low cost fuel.

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, and 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: (1) novel,

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innovative concepts and processes to produce carbon materials, or precursors, from coal or coal-derived sources that can be economically competitive, or exhibit superior performance characteristics, compared to petroleum-based precursors; (2) novel coal-derived carbon materials that can be substituted in commercial products that currently utilize petroleum-based carbon; and (3) new products, based on carbon-derived material, that are not currently commercial.

c. Indirect Liquefaction Technologies for Fuels and Chemicals—The conversion of coal into liquid fuels is not currently economically competitive using existing processes. Indirect liquefaction via synthesis gas production provides an environmentally sound route for producing transportation fuel and high value chemicals. While several commercial processes exist that involve synthesis gas conversion, the main impediments to the further development of these processes is the high cost of the production and purification of synthesis gas and the low productivity of current synthesis gas conversion processes. Grant applications are sought for: (1) innovative concepts for reducing the cost of synthesis gas produced from coal and other carbonaceous feedstocks (e.g., petcoke, waste, biomass); (2) novel technologies for converting synthesis gas to environmentally superior transportation fuels or high-value, strategically important chemicals; and (3) innovative processes for hydrogen separation from mixtures of hydrogen, carbon monoxide, carbon dioxide, and hydrogen sulfide.

d. Conversion of Coal—Direct liquefaction refers to the direct hydrogenation of coal to produce liquids. Grant applications are sought to develop innovative reaction concepts and catalyst systems (fixed-bed or disposable) to promote more efficient conversion reactions. The emphasis is on significant process cost reduction. Approaches may include developing additional knowledge of reaction chemistry as well as novel biological approaches.

Heavy oil processing refers to the upgrading of difficult to process heavy petroleum residuums via coprocessing with coal or other hydrogen addition and carbon rejection processing techniques. Grant applications are sought for novel methods for coprocessing organic wastes (such as plastics, paper, tires, and used oils) with coal and/or heavy petroleum residue, resulting in more valuable upgraded liquid products. These organic waste materials are becoming increasingly more costly to dispose of in landfills, and now represent a lost fuel resource.

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25. NATURAL GAS UTILIZATION

The DOE is funding efforts to develop and demonstrate advanced technologies for the utilization of natural gas. Successful commercialization of these advanced technologies will reduce national fuel use because of improved efficiency, while providing benefits to the U.S. environment and economy. The DOE is interested in innovative research to support these developments. The design and development of fossil fuel processes must consider possible adverse effects on the environment. New environmental protection requirements are constantly under consideration by the EPA, Congress, States, and others, as laws are reauthorized or amended.

Innovative research can contribute to all facets of natural gas utilization - including methods for upgrading, storage, and delivery; the efficient production

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of electricity in advanced gas turbine systems; and the development of high-temperature fuel cells. **Grant applications are sought only in the following subtopics:**

a. Advanced Gas Turbines—Materials, components and systems concepts are needed for ultra-high-efficiency gas turbine power systems. Grant applications are sought to develop (1) thermal barrier coatings, bond coatings, ceramic components, composite materials, high temperature alloys, or advanced seals; and (2) techniques for catalytic low NO_x combustion, combustion noise control, advanced cooling concepts, or performance monitoring. Grant applications must demonstrate that the proposed innovation will contribute directly to the goals of the DOE Advanced Turbine Systems program (see references 1 and 9). Innovations may address requirements for natural gas-fired systems or for systems adapted to coal-derived fuel gas. Applications that focus only on systems studies and analysis of cycle efficiencies will be declined.

b. High-Temperature Fuel Cells—High temperature solid oxide (above 800° C) and molten carbonate fuel cell technologies are important for stationary electric power generation. Grant applications are sought to develop innovative designs, improved materials and manufacturing processes, and supporting components for high-temperature fuel cells that can improve performance, increase operating life, and lower system cost. Grant applications are also sought for the integration of high temperature fuel cells and gas turbines to achieve high efficiency electric power generation systems. Applications should address innovations in integrated concepts as well as specific materials, components, and equipment. Applications that focus only on systems studies and analysis of cycle efficiencies will be declined.

c. Natural Gas Upgrading—Some domestic supplies of natural gas contain large amounts of non-methane gases which make them uneconomical to market as natural gas. The removal of these non-methane impurities could have significant economic benefits. Grant applications are sought to develop small scale facilities to raise low-quality raw natural gas to pipeline quality using membranes, absorption/adsorption, and/or hybrid combinations of these technologies. Grant applications that address the removal of hydrogen sulfide from natural gas must also account for its subsequent or direct conversion to elemental sulfur or other environmentally benign products.

d. Natural Gas Storage—Grant applications are sought for innovative and cost-effective methods to improve the deliverability and capacity of natural gas storage reservoirs and to improve measurement and automation of gas flow from storage facilities. Topics of interest include (1) new or improved automated methods and sensors for the measurement of gas flow, composition, BTU, and total energy, which can be cost effectively installed at individual injection/withdrawal wells or at storage facilities; (2) cost-effective innovative or improved storage capacity for industrial/power generation users; (3) new or improved methods to revitalize deliverability from existing storage wells, including stimulation methods; (4) methods to optimize new or expanding storage field development; and (5) cost-effective methods to reduce gas trapping in aquifer storage. Applications must emphasize how the proposed research differs from existing technology.

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* See Section 7.1

26. ADVANCED OIL AND GAS TECHNOLOGY

The DOE seeks innovative methods and concepts that will contribute to more efficient and economic exploration, production, and refining of domestic oil resources. This includes improved exploration techniques to find domestic oil resources, improved technology to maximize domestic oil production, and improved refining techniques to yield as much high quality fuel and lubricants as possible.

The DOE also seeks innovative processes and concepts that will allow more efficient, economical, and environmentally acceptable recovery of natural gas. Novel improvements in recovery techniques could lead to lower production costs and/or greater recovery efficiencies. The DOE's interests in drilling, completion, and stimulation are to lower capital investment, increase process efficiencies, and minimize formation damage. Collectively, these objectives are expected to reduce the unit cost of accessing and producing natural gas. **Grant applications in support of the above areas of interest are sought only in the following subtopics:**

a. Reservoir Characterization—Grant applications are sought for innovative methods to characterize oil and gas reservoirs in terms of reservoir architecture (including low permeability natural gas fracture system orientation), reservoir geometry boundaries, boundaries through time, and fluid/rock and fluid-flow properties. Reservoir characterization methods of interest include high-resolution seismic techniques; improved geological mapping, prediction and analysis techniques; and innovative software techniques (i.e., utilizing three-dimensional seismic and other well logging data to determine heterogeneity and fluid flow in reservoirs).

b. Analytical Techniques for Oil Exploration—Grant applications are sought to develop geologic modeling, risk assessment, and risk-based decision making techniques to reduce the cost and improve the outcome of exploratory drilling. Models and techniques should utilize fracture analyses, remote sensing data, geochemical methods, and other low impact technologies in order to explore sensitive or remote areas. Modifications to existing techniques as well as completely novel approaches are of interest.

c. Oil Recovery Processes—Over one-half of the U.S. oil was imported at a direct cost of about $1 billion/week in 1996; yet, only one-third of the discovered original oil in place has been recovered. The remaining two-thirds (more than 350 billion barrels) of this oil cannot be economically produced at current prices with today's technology. Grant applications are sought to improve upon existing oil recovery processes (e.g., water flooding, pressure maintenance, sweep improvement, completions/stimulations, infill drilling, and horizontal wells), and to develop advanced extraction techniques (e.g., chemical flooding, gas flooding, and microbial and thermal methods) to make even more of this remaining target recoverable.

d. Natural Gas Drilling and Production—Innovative approaches are desired to reduce the cost of drilling natural gas wells while improving or maintaining safety, and minimizing environmental disturbance. Grant applications are sought for products, technologies, systems, and methods to (1) increase the rate-of-penetration, (2) cut medium-to-hard, abrasive formations, (3) enhance directional and horizontal well, slimhole, and under balanced drilling and completion technology, (4) demonstrate novel stimulation concepts, and/or (5) improve completion hardware.

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27. ADVANCED COAL-BASED POWER SYSTEMS

The DOE is supporting the development of new, coal-fired power plants based on advanced coal technology with the potential for high efficiency, low emissions, and reduced cost relative to today's coal-fired generating plants. These systems include advanced pulverized coal combustion with both direct- and indirectly-fired cycles, integrated gasification combined cycle (IGCC), and pressurized fluidized bed combustion (PFBC). New concepts are needed to further improve the performance and efficiency of these systems.

In addition, the design and development of coal-based processes must consider possible adverse effects on the environment. Coal is a solid fuel containing elements that are precursors of environmental pollutants or substances that are potentially damaging to downstream system components, such as turbines. These pollution-causing elements include nitrogen and sulfur, which form undesirable oxides during combustion. Further,

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coal contains potentially hazardous trace elements (mercury, cadmium, arsenic, nickel, selenium and chromium) that may be emitted to the environment. Fine particulates emitted from coal-fired plants are also a health concern. There is also concern about the effect of carbon dioxide produced from coal combustion on the global climate. New technologies are needed to characterize and reduce emissions of air pollutants resulting from coal combustion and coal gasification processes used in advanced power generation systems. **Grant applications are sought only in one of the following subtopics:**

a. Advanced Pulverized Coal-Fired Power Generation Systems—Highly advanced power plants based on pulverized coal combustion technology will utilize ultra-low NO_x combustion systems and SO_2 control systems that minimize the amount of waste generated or produce saleable by-products. By the year 2000, thermal efficiency should reach 42 percent with supercritical steam cycles and 45-50 percent with newly developed cycles that use two-component working fluids (such as the ammonia-water-based Kalina cycle). The cost of electricity should be reduced by 10 percent or more relative to today's coal-fired plants.

Grant applications are sought to develop (1) technology for minimizing NO_x formation in cyclone-fired boilers or wet-bottom slagging combustors, which would reduce overall plant cost for NO_x emission control and for waste disposal, and (2) advanced combustion control diagnostics that provide continuous on-line measurement and control of the fuel and air flow rates for each burner, or at specific locations in the boiler or coal combustor.

b. Removal of Contaminants in Integrated Gasification Combined Cycle Systems—In an IGCC system, coal is converted into a gaseous fuel, which, when cleaned, is comparable to natural gas. Over 99 percent of the coal's sulfur and particulate contaminants are removed before the fuel gas is burned in a high-efficiency combustion gas turbine/generator. The hot turbine exhaust gas produces steam to drive a steam turbine/generator. Today, several IGCC technologies in various stages of commercial demonstration have expected installation costs of $1,500 to $2,000 dollars per kilowatt and plant efficiencies around 40-42 percent. The DOE seeks to achieve plant efficiencies of 45 percent and 52 percent, and capital costs of $1,200 and $1,050 per kilowatt, by the years 2000 and 2010, respectively. Grant applications are sought to develop (1) novel, effective, economic, and efficient processes and/or devices for removal of physical and chemical contaminants independently or in combination from coal gasification streams to levels that meet gas turbine and/or environmental emission requirements, (2) novel systems (reactor concepts, reagents) to decompose ammonia and other sources of fuel-bound nitrogen in IGCC fuel gas streams separately or in combination with sulfur removal and/or to cleanly combust fuel gas with minimal NO_x production, (3) innovative, low cost, and reliable systems for sulfur removal and subsequent recovery (dry sorbent or liquid systems) from the pressurized IGCC fuel gas at high temperatures (i.e., above the dew point of the gas), and (4) novel, low cost, long life, reliable barrier filter systems and components (i.e. filter elements) for high pressure, high temperature (700°F - 1100°F) particulate removal in IGCC gas streams.

c. Systems for Pressurized Fluidized-Bed Combustion—In PFBC systems, high system efficiency results from a combined-cycle configuration, which includes a conventional steam cycle and a gas turbine. Limestone or dolomite mixed with coal in the fluidized-bed removes the coal's sulfur, eliminating the need for post-combustion flue gas desulfurization. Lower combustion temperatures and air staging reduces the amount of nitrogen oxide emissions. Ceramic filters are used to clean the hot gases from the pressurized fluidized-bed combustor. PFBC technology is on the brink of commercialization, with first-generation power systems capable of net system efficiencies approaching 42 percent and with installation cost expectations ranging from $1,300 to $2,000 dollars per kilowatt. The DOE seeks to achieve PFBC system efficiencies of 45 and 52 percent, with capital costs of $1,100 and $1,000 per kilowatt by the years 2000 and 2010, respectively.

Grant applications are sought to develop (1) novel gas turbine compatible fuel gas combustion systems that can boost gas temperatures entering the gas turbine into the 2,600°F range with minimal NO_x production; (2) novel low-cost, long-life barrier filter systems for high-pressure, high-temperature particulate removal in PFBC gas streams; (3) devices for simultaneously removing particulates and chemical contaminants independently or in combination to levels that meet gas turbine and/or environmental emission requirements; and (4) novel concepts and equipment configurations that allow the fuel-flexible nature of fluidized-bed combustion systems to improve operating stability (e.g., J-value, N-value, standpipe dense flow fluid dynamic simulations) and to reduce operating costs through the introduction of opportunity fuels (such as high sulfur coal, petroleum coke, and municipal waste sludges) and/or sorbents.

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d. Emission Control Technology for Coal-Fired Power Plants—Grant applications are sought to develop (1) measurement and monitoring technologies for particulate matter less than 2.5 micron size (PM2.5) consisting of flyash particles, and sulfate and nitrate aerosols formed as a result of sulfur dioxide and nitrogen oxide emissions, (2) hazardous air pollutant control technology, especially for mercury, that remove the pollutant with 90 percent or greater efficiency, and devices for measuring and speciating mercury emissions, (3) economic recovery of a strategic metal (e.g., aluminum) from coal ash that would provide a stable supply of a raw product for metal industry and for the utilization of a waste material, and (4) methods of CO_2 disposal, from abandoned and depleted oil and gas reservoirs in the deep ocean and from deep confined aquifers, which are technically, economically and ecologically feasible (demonstrated in Phase I by mostly analytical research with small scale experiments).

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* See Section 7.1

** See Section 7.2.

*** Available from American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017. Telephone 800-843-2763.

28. TECHNOLOGY FOR COMMERCIAL NUCLEAR POWER PLANTS AND SPACE NUCLEAR POWER SYSTEMS

The continued viability of commercial nuclear power, during the current operating term and through a license renewal period, will require appropriate characterization and demonstration of materials performance for those systems, structures and components considered critical for the safe and economic operation of a nuclear facility. Innovative technology-based research and development is needed to enhance commercial light water reactor (CLWR) technologies and techniques to (1) measure mechanical properties and improve inservice inspection characterization of nuclear reactor pressure vessel materials; (2) model, detect, and mitigate stress corrosion cracking in sensitive reactor system materials; and (3) characterize and predict environmental aging behavior of electrical cable jacket and insulation materials.

In addition, the DOE supports research and development of technologies for the application of radioisotope power systems to the space missions of other U.S. government agencies. Spacecraft electrical power is needed for such missions as deep space exploration and Mars surface exploration (see references 19 and 25). 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 Mechanical Properties Testing, Characterization, and Inservice Inspection Technologies for Reactor Pressure Vessel (RPV) Materials—Present approaches to characterizing RPV integrity include: (1) destructive testing of surveillance specimens to monitor the mechanical properties of materials susceptible to irradiation embrittlement, and (2) inservice inspection to verify the absence of service-induced defects in RPV beltline materials (materials directly adjacent to the effective height of the nuclear fuel core) in accordance with Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. Regarding (1), research and development needs include innovative mechanical property measurement techniques to significantly reduce the volume of surveillance specimen material for destructive testing, and improved nondestructive techniques for direct mechanical property measurements. Regarding (2), 100 percent inspection of all examination volumes is required to provide an accurate assessment of RPV integrity. (In the past, the Nuclear Regulatory Commission has granted relief requests if physical constraints precluded 100 percent inspection; however, these requests are not expected to be granted in the future.) Also required is the characterization of inspection system performance parameters, including probability of detection and sizing

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accuracy. Additionally, the associated measurement uncertainty is needed for acceptance of these techniques.

Grant applications are sought to develop: (1) destructive examination techniques to determine mechanical properties (Charpy impact, tensile, fracture toughness) of RPV materials subjected to irradiation embrittlement, using the smallest possible surveillance specimen; (2) *in-situ* nondestructive examination technologies for irradiated, embrittled RPV materials, in which output signals are correlated with mechanical properties (Charpy impact, tensile, fracture toughness); (3) *in-situ* nondestructive examination techniques that ensure 100 percent inspection of all ASME Section XI examination volumes; and/or (4) techniques to determine the flaw size-dependent probability of detection, as well as the sizing accuracy of RPV nondestructive inspection systems.

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. Presently, hydrogen water chemistry systems are used to manage this phenomenon; however, adequate control of the BWR water chemistry to effectively reduce SCC for internal components may result in an increase in ^{16}N radiation fields around the main steam system which may increase shutdown radiation fields. Consequently, hydrogen water chemistry systems may not be fully effective in managing this problem. In addition, irradiation assisted stress corrosion cracking (IASCC) of pressurized water reactor (PWR) internal components may soon occur at older plants as neutron fluence approaches predicted IASCC thresholds. For PWRs, the main concern is detecting IASCC and establishing an appropriate IASCC threshold.

A multi-faceted approach is needed to manage reactor internals material behavior such as (1) technologies to mitigate degradation, including changing the environment, (2) examination techniques to find incipient defects before cracking occurs, and (3) crack growth prediction methodologies that fully incorporate environmental conditions and allow for component-specific considerations. For BWRs, some multiple approaches to altering the environment are being considered (e.g., enhanced hydrogen water chemistry and injection of noble metals). The complex geometry of most reactor system internal structures makes it very difficult to perform volumetric examinations - most SCC of BWR internal components have been detected by visual examinations. Finally, crack growth models that accurately predict SCC and IASCC of even simple structures are not available. 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 system internals to ensure safety.

Grant applications are sought in the above CLWR areas to develop (1) mitigation technologies, especially approaches that reduce SCC without causing other adverse effects or environments; (2) nondestructive examination techniques for early detection of SCC in reactor internals materials; and/or (3) SCC modeling techniques that significantly improve reactor internals material behavior predictions.

c. Environmental Aging Inspection and Testing Technologies for Electrical Cable Jacket and Insulation Materials—In commercial nuclear power plants, electrical cables are subject to various types of environmental aging in many critical applications. Essential cables are typically required to function for all modes of operation, even during and after severe postulated events which could occur at the end of the plant's life (i.e., after a lifetime of thermal and irradiation aging under normal operating conditions). The ability of an electrical cable to perform its safety function(s) is dependent on the condition of the cable's jacket and insulation materials. Since additional aging could occur during and after such an event, cables must have some reserve margin. Grant applications are sought for technologies that allow *in situ* testing of CLWR electrical cables to: (1) determine cable jacket and insulation material condition, (2) predict the remaining life of a cable, and (3) assess the ability of a cable to perform its safety function(s) during postulated 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 from very localized samples are also of interest.

d. Radioisotope Power Systems—Radioisotope Power Systems (RPS) employing thermoelectric conversion have provided spacecraft electric power source for deep space exploration and have been used in moon and Mars surface missions (see references 19 and 25). While thermoelectric RPSs have been extremely reliable, with operational lives of more than 20 years, their system efficiencies are low (typically 6.5 to 9 percent). For static systems, grant applications are sought to attain conversion efficiencies $\geq$ 16 percent, in power ranges of 10 to 150 watt electrical, with mission lives in the range of 10

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to 25 years. Approaches could employ, but are not limited to, conversion systems based on one of the following technologies: a new thermo-electric material and device, a thermophotovoltaic (TPV) system, or an Alkali Metal Thermoelectric Converter (AMTEC) system. For thermoelectric conversion, target device efficiency is 12-16 percent using new advanced materials such as "quantum well" or segmented couple designs. For TPV (see references 19, 24, and 25) and AMTEC (see references 19 and 25) systems, the target system efficiency is $\geq$ 20 percent. Areas of interest include innovations in TPV cells which increase their operating temperature capability, and innovations in AMTEC systems (see references 19 and 25) or components which lead to significant improvements in system life (i.e., $\geq$ 10 years).

Grant applications are also sought to improve the performance of Stirling linear power conversion systems in the power range 50 to 150 watts electrical. Areas of interest include innovations in alternator design to increase efficiency and lower system weight; design features which yield very low (approaching zero) dynamic inputs at the mounting structure interface; application of Stirling space cryocooler technology to the power generation, providing the high temperature materials problems are adequately addressed; methods to attain high thermal efficiency in heat source system integration; and design methodology which permits scaling for a range of power levels.

Thermal systems and materials compatible with a heat source based on the general purpose heat source module (see reference 21) are desirable. The maximum heat source steady state temperature is approximately 1330°C for the fuel clad surface, which for a vacuum system yields a module surface temperature of approximately 1100°C. Grant applications for advanced heat source designs and systems compatible with advanced heat sources will be considered.

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** Available from the Nuclear Regulatory Commission's Public Document Room, Washington, DC, 20555. Telephone 1-800-397-4209 or 202-634-3273.
*** See Section 7.2
† See Section 7.1.

29. SENSOR COMPONENTS FOR NONPROLIFERATION AND NATIONAL SECURITY

There are several treaties in place and being negotiated that enforce international nonproliferation and national security goals related to weapons of mass destruction and the missiles and other delivery systems for such weapons. These treaties include Nuclear Nonproliferation Treaty, Strategic Arms Reduction Treaty, Chemical Weapons Convention, Comprehensive Test Ban Treaty and Fissile Material Cutoff Treaty. Other national security initiatives include detecting illegal diversion of weapons useable material (nuclear, chemical, biological and explosives) and working with the former Soviet Union to improve material protection, control, and accountability. Implementation of these treaties and initiatives requires deployment of advanced sensors by satellite, aircraft, onsite inspections and cooperative regional monitoring. The following research and development areas represent gaps in current technology that would significantly help sensor development efforts by improving sensitivity, expanding detection capabilities to new targets of interest, making detection instruments portable, and making it cheaper and easier to integrate sensors into unattended monitoring systems. **Grant applications are sought only in the following subtopics:**

a. Miniature Quadrupoles and Turbo Pumping Systems for Mass Spectrometry—There is a need for small field portable analysis instruments to aid in onsite inspections for treaty verification, intelligence gathering, and forensics analysis for nuclear smuggling. One technique used for this application is gas chromatograph mass spectrometry. Grant applications are sought for the development of cost effective, miniature quadrupole

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and/or turbo molecular pumping systems for gas chromatograph mass spectrometry. The quadrupole spectrometer must have a sensitivity better than one part per billion (of particular interest are innovative approaches resulting in one parts per trillion or better sensitivity), must have a detection range of zero to 650 atomic mass units (AMU) with resolution plus or minus 0.5 AMU, must use a temperature source greater than 175 degrees Celsius, and must be less than twelve inches long. The miniature turbo molecular pumping system must be capable of pumping 30 liters per second of nitrogen gas (from atmospheric pressure to 10^{-7} torr), weigh less than 3.6 kilograms, be relatively small in size compared to current systems and have an integrated micro rough pump capable of pumping 15 liters per minute (atmospheric pressure to 10^{-3} torr).

b. Light Sources for Chemical Spectroscopy—Advanced light sources are needed for improved capability to perform chemical spectroscopy, which would allow the development of small, portable analysis instruments for onsite and remote applications. There are three specific areas of interest: (1) there is a need for optical excitation sources (light emitting diodes) in the 420 nanometer and 500 nanometer wavelength. Grant applications are sought for the development of an inexpensive light source with approximately one milliWatt power output (~1000 candela), approximately 1000 hour lifetime, and a peak emission of 420 nanometers or 500 nanometers plus or minus ten nanometers; (2) recently, fabrication methods have been perfected that allow quasi-phase matched (QPM) nonlinear materials to be generated. The most notable example of this is periodically-poled lithium niobate (PPLN). The use of PPLN has enabled the development of continuous-wave (cw) optical parametric oscillators (OPOs) that have performance characteristics that were not achievable in the past (1-4.5 micrometer wavelength access, 2-3 W output power). These lasers are extremely promising sources for both point and remote chemical sensing. The utility of PPLN-based OPOs could be dramatically increased if a device could be fabricated with a significantly lower lasing threshold than the current level of 3-4 W. Therefore, grant applications are sought to develop a low-threshold cw OPO that is capable of tunable operation in the 2800-3500 wavenumber (2.86-3.57 micrometer) range. Line widths of 0.1 wavenumbers or less are required. The threshold must be low enough to allow operation with an air-cooled Nd:YAG laser pump source or, ideally, with a diode laser pump source; and (3) development of non-linear crystal materials to be used for frequency doubling and wavelength shifting of 10 micron input light. The crystals must have a nominal cross section of 1 cm or more and produce high conversion efficiency (greater than 30 percent) at moderate power levels that are significantly below the crystal's damage threshold. The crystals should have low optical loss and allow phase matching over a large (20 percent) bandwidth. The ability of the crystals to tolerate reasonable temperature and humidity fluctuations is required. Manufacturing methods that allow the low cost production of these optical devices must be demonstrated.

c. Expanding Capabilities for Unattended Facility Monitoring Applications—Unattended facility monitoring requires integration of many types of sensors (including video, radiation, chemical, motion, and tags and seals) into systems, and the monitoring scenario changes for each application. The DOE's Cooperative Monitoring Research Program and DOE's International Remote Monitoring Program are using Lonworks technology (see reference 3) to integrate sensors for facility monitoring applications around the world. The goal is to achieve sensor "plug and play" so that DOE developed sensors, commercial sensors and foreign developed sensors can inexpensively and easily be integrated into unattended-remote monitoring systems. Technology improvements are still needed to make this an inexpensive and easy process. Therefore, grant applications are sought for low cost solutions to improve the Lonworks technology for unattended facility monitoring applications. Grant applications must address one or more of the following areas of interest: low power wireless communication transceivers (radio frequency, infrared, etc.); innovative techniques to efficiently transmit high volumes of data over the same communications network while maintaining the integrity of the network; and flexible and user friendly data acquisition, display, and network configuration tools. Significant improvement over current capabilities must be demonstrated.

d. Long Wave Infrared (LWIR) Detection and Amplification—High sensitivity detection of optical radiation in the LWIR (8 to 12 microns) is a vital concern to both passive and active remote sensing. Grant applications are sought for the development of both single element and multiple-element detector arrays that have extremely low noise (less than 100 pW) and low capacitance (less than 1 Pico Farads). Areas of primary interest include arrays with detector/pixel diameters between 20 and 100 microns and unconventional detectors with intrinsic gain and fast (microsecond) recovery rates. Grant applications must demonstrate that highly uniform detectors with quantum efficiencies in excess of 0.7 can be reliably produced and that the

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detector arrays are combined with data analysis software to effectively optimize detector alignment. Efficient operation without the use of cryogenic cooling would be a distinct advantage.

Grant applications are also sought for electronic amplifiers to boost the signal from LWIR detectors. Amplification circuitry with a noise equivalent power (NEP) less than 100 pW and a bandwidth approaching 20 MHZ are highly desirable. Schemes to integrate the initial amplification stage with the detector inside the cryostat (reducing microphonics and amplifier thermal noise) would be of great interest. This includes the development of cryogenically cooled transistors. The circuitry should be applicable to gated detection with gate widths in the 10 to 100 nanosecond range.

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30. DETECTION AND CHARACTERIZATION OF ILLICIT ACTIVITY FOR NONPROLIFERATION AND NATIONAL SECURITY

Identifying illicit activity over a broad geographical area is a very difficult problem. Vast amounts of data are generated from the various techniques used and it is difficult to analyze all the data and find pertinent information. In some cases, such as in identifying underground facilities, sensors are not capable of detecting targets of interest, let alone perform searches over a broad area. The purpose of this topic is to improve the tools, sensors, and visualization capabilities for these applications. **Grant applications are sought only in the following subtopics:**

a. Broad Area Search Analysis Tools—A broad area search for proliferation facilities is a difficult problem, particularly if the facility is contained in an underground structure. One way to narrow the search is to take advantage of the facilities dependance on the national infrastructure. Examples of infrastructure include

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power lines, power plants, communication lines and facilities, roads, railroads, canals, navigable rivers, airports, tunnels, water supplies, pipelines, docks, warehouses, industrial parks, and military reservations. The capability to delineate the distribution of the national infrastructure is extremely important. Due to the shortage of trained analysts to pull this information from remote sensing data, the process should be automated wherever possible. Therefore, grant applications are sought for the development of novel approaches to automate the detection and classification of components of the national infrastructure using remote sensing data. In addition, approaches must be able to perform periodic searches for changes to the national infrastructure, estimate the capacity of components of the national infrastructure, estimate the degree and quality of use of the components of the national infrastructure (e.g. traffic analysis), and, from this information, guide the search strategy used to detect, classify, and assess proliferation facilities. The access and display of information must be user friendly, such as through an object oriented geographic information system.

b. Underground Structures/Facility Detection—Detecting and characterizing underground structures or facilities that are being used to conceal illicit activities is one of the most difficult problems for the nonproliferation and national security community. Currently geophysical and remote sensing techniques are widely used, but they do not meet the detection range (depth), sensitivities and user friendly operation needed for practical applications. Grant applications are sought for the development of new and innovative techniques that significantly improve the capability to identify and/or characterize buried structures and facilities. Approaches with high risk and large payoffs are encouraged.

c. Data Exploitation via Virtual Reality—Virtual reality techniques have yielded good results as a data analysis tool in many applications. However, their use in the analysis of data from sensors in nonproliferation and national security applications has remained limited. Grant applications are sought to develop virtual reality data analysis tools for applications described in subtopics 'a' and 'b' above, as well as for unattended remote monitoring applications such as virtual onsite inspections performed by treaty verification organizations, and others described in reference 3.

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31. TECHNOLOGY DEVELOPMENT FOR DOE EMERGENCY RESPONSE TEAMS

The DOE facilities maintain protective forces and emergency response teams to protect critical DOE assets including special nuclear material and to respond to potential terrorist activities such as an attack using weapons of mass destruction (nuclear, chemical and biological warfare). These resources are also available for civilian applications on request by various entities such as local law enforcement, customs agents, fire fighters, and emergency medical response personnel. As the threat for terrorist activity increases it is important to improve the capabilities of these emergency response teams by exploiting new and innovative technologies. **Grant applications are sought only in the following subtopics:**

a. Decontamination of Chemical and Biological Agents—DOE Special Response Teams must be capable

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of responding to terrorist incidents in which chemical or biological agents are used. Grant applications are sought for the development of chemical and biological agent decontamination methods and for protective clothing worn during these efforts. Decontamination methods must be suitable for use in a cluttered environment (buildings, offices, etc.) as well as in open terrain, must be easy to apply, and have a rapid response time. Approaches related to protective clothing must result in light weight, low cost, single use apparel capable of protecting personnel for periods of 4-8 hours from both chemical and biological agents, and must also be compatible with existing equipment used by DOE's emergency response and protective forces (tactical, load bearing vest and a web belt for small arms holster and other duty equipment).

b. Biological Point Detection—Perhaps the single most difficult job in protecting against weapons of mass destruction is the reliable detection and identification of biological toxins and organism. Effective response to incidents involving biological agents requires improvements in all areas of detection. Grant applications are sought for reliable biological agent detectors that are easy to use in either portable or unattended modes, applicable to a broad suite of agents, and produce minimal false alarms. Applications must address all aspects of sensor development, from detection to data evaluation. Where necessary for the appropriate interpretation of biological sensor data, grant applications should also address concomitant advances in associated databases, interpretative algorithms, or other aspects of the evaluation process.

c. Flash Suppressor—In the event of a hostile act at any of the DOE's facilities, protective forces may respond to fixed posts to return fire. By firing their weapons, the protective forces would give off a visual signature that announces their positions to the adversary by muzzle flash. Technology to suppress this visible signature from fire arms is not presently available. Therefore, grant applications are sought for the development of a flash suppressor that can completely eliminate the visual signature of a fire arm. Weapons used by DOE protective forces include, among others, M-16, M-14, and 300 Win Mag rifles.

d. Personnel and Vehicle Tagging—In the event that critical assets, such as special nuclear material, are stolen from a DOE facility, a reliable, small tagging device would be extremely valuable in maintaining contact with a fleeing assailant. Grant applications are sought for the development of technology that can be attached to a mobile target that will allow continuous monitoring and identification. The technology must provide location data and transmit that data at a range of no less than 20 miles. The package must be able to operate in all environmental conditions for a period of no less than 10 days. The package must have a low profile to enable concealment and must be easy to attach to the target.

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32. NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

The 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 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

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nuclear physics program. **Grant applications with applicability to nuclear physics research clearly noted are sought only in the following subtopics:**

a. Detectors and Detector Materials—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, 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; (6) large arrays of high-resolution, room-temperature HgI_2, cadmium-zinc telluride or other appropriate x-ray and gamma-ray detectors for use in nuclear spectroscopy relevant to nuclear physics research (minimizing Compton scattering of reaction gamma rays requires that the mass of detector packaging and associated electronics be reduced as much as possible); and (7) resistive materials and methods of production of large area (>100 cm^2) conductive surfaces with resistivity in the range of 10^{10} to 10^{12} Ω-cm for electrodes in gas chamber counters, such as substrates in gas micro-strip counters.

b. 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 particle detectors used in nuclear physics experiments such as gas detectors, scintillation counters, silicon drift chambers, silicon strip detectors, particle calorimeters, and Cherenkov counters. Representative circuits include low noise amplifiers, analog storage devices, analog-to-digital and time-to-digital converters, 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 pixelated 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, generalized software, and hardware packages with improved graphic capabilites for the acquisition and analysis of data specifically adressing needs related to nuclear physics research and development.

c. 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.) Grant applications are sought for hardware and software techniques to improve the cost-effectiveness of handling such large data volumes.

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

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* See Section 7.1

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33. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program of the 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 Jefferson 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:**

a. Materials and Components for Radio Frequency Devices—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

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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 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) methods to convert RF power, induced in superconducting cavities by decelerating beams, to direct current (dc) power (the RF power should be induced at a single frequency between 500 and 1500 MHz, and the conversion efficiency needs to be greater than 50 percent); (7) high duty factors, high power RF systems for radio frequency quadrupoles and linacs; and (8) 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).

c. Particle Beam Sources and Techniques—Grant applications are sought to develop (1) high-brightness electron beam sources utilizing continuous wave superconducting RF cavities with integral photocathodes operating at high acceleration gradients; (2) 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; (3) 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 heavy ions); (4) 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); (5) methods to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers or special stripping techniques); and (6) power supplies to drive these 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 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. Measurements of dc 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

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34. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The DOE High Energy Physics program supports a broad research and development effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced research and development (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 or heavy ion fusion is specifically excluded from this topic and should be submitted under Topics 33 and 41, respectively. **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. These concepts may include related subsystems, technologies, and devices. Stageability, beam stability, manufacturability, and high wall plug to beam power efficiency must be addressed in detail. Grant applications must also address the marketability of any systems, technologies, and devices to be developed.

b. Novel Device and Instrumentation Development—Grant applications are also sought for the development of electromagnetic or permanent magnet based charged particle optical elements for particle beam

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focusing. Examples include, but are not limited to, dipoles, quadrupoles, higher order multipole correctors for use in small electron linear accelerators, and solenoids for use in electron-beam or ion-beam sources or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.1 to 10 cm. Permanent magnets in these optical elements which are made 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 spectra of these beams (proposed techniques must be nondestructive to the beams monitored and have computer-compatible readouts); and (3) compact multi-terawatt laser systems are sought for laser-accelerator applications.

Regarding (3) above, multi-terawatt laser systems must be capable of providing approximately 1 J energy in 50 femtoseconds in ultra-short pulse, single frequency operation at a high (around 10 Hz or greater) repetition rate. Alternately, such a system must be capable of providing approximately 60 J energy in 4 picoseconds in dual frequency (near 1.05 micrometer and 1.06 micrometer) operation with a repetition rate of better than 2 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 radio frequency linac to a high level of precision (less than approximately 1 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 to provide, 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 sought for research and development leading to rugged, long-life cathodes or electron guns that are capable of producing current densities and currents (several hundred amperes pulsed) comparable 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, and on semiconductor photocathode sources of electrons with polarization in the range of 80 percent and energy in the range of a few volts to several hundred kilovolts.

d. Computer Software—Grant applications are invited 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

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and windows. Grant applications are also sought 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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** See Section 7.1

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

The 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) low-cost, very efficient, pulse power modulators. Relevance to applications in high energy physics must be explicitly described. Advanced accelerator R&D more appropriate to applications in nuclear physics or heavy ion fusion is specifically excluded from this topic and should be submitted under Topics 33 and 41, respectively. **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)

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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 in 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.

The next generation linear collider will require many radio frequency power handling components which are not presently available, e.g., rf windows, couplers, mode transformers, rf loads, and high power rings capable of operating at high pulse powers (20 - 100 MW), high frequencies (11 - 100 GHz), and several microsecond pulse lengths. Examples of 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. 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 modulators in the 400 kV- 1 MV range for driving currents of 400 - 800 A, with pulse lengths of 0.2 - 2 microseconds, and rise- and fall-times of less than 0.2 microsecond. The development of improved capacitors for energy storage in such systems is also sought. 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.

Grant applications are also sought for new 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. These devices can be operated with simple direct current 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.

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36. ADVANCED CRYOGENIC, HIGH-FIELD SUPERCONDUCTOR, AND SUPERCONDUCTING MAGNET TECHNOLOGIES FOR HIGH ENERGY PARTICLE COLLIDERS

The 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. **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 special 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 multi-filament wire with low stabilizer (Cu, Al) to superconductor ratio, for use in very high-field magnets (B >8 T). Applications must demonstrate such property improvements as higher critical-current densities, higher critical fields, reduced degradation of these properties as a function of applied strain, or equivalent performance at reduced cost. Advanced conductor fabrication techniques of interest also include methods to utilize high aspect ratio strands or tape geometries. Materials of interest include: niobium-titanium, niobium-tantalum-titanium, the so called "A-15" compounds (e.g., niobium-tin), and oxide (high temperature) superconductors. Regarding oxide superconductors, a minimum current density of 1000 A/mm^2 (not cm^2) in the superconductor itself and a minimum current density of 200 A/mm^2 over a total conductor cross section, at 12 Tesla minimum, must be produced.

In addition, grant applications are sought for innovative insulating materials which would enable use of new superconductors, such as the A-15 or oxide type superconductors. Insulating materials must be compatible with high temperature reactions in the 750-900°C range, and must be capable of supporting high mechan-ical 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) 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 — designs that are more compatible with the more fragile A-15 and high temperature, high-field superconductors.

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37. HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

The DOE supports research and development in a wide range of technologies essential to experiments and particle accelerators used for high energy physics research. The development of advanced electronics and computational technologies for the recording, processing, 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. **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.

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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 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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38. HIGH ENERGY PHYSICS DETECTORS

The 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). 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. **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 included, but are not limited to, solid-state detectors (silicon strip, silicon pixel, photodiode), photosensitive detectors (photomultipliers, microchannel 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., energy, position, and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, radiation hardness).

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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39. PLASMA PHYSICS AND DIAGNOSTICS

The newly redirected Fusion Energy Sciences program is increasing its emphasis on improving fusion plasma performance and expanding the scientific understanding of plasma behavior. The program currently supports several magnetic fusion experiments that have many common needs and problems where innovative research and development could benefit the entire magnetic fusion experimental program. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts in the areas of plasma heating and particle control, complete diagnostic systems for measuring plasma parameters, improve performance of currently used systems, and improve capabilities for data analysis. Excluded from this topic is research and development pertaining to cold fusion, inertial confinement fusion, and other fusion energy concepts that are not based specifically on the magnetic confinement of plasmas. **Grant applications are sought only in the following subtopics:**

a. Plasma Heating—Radio frequency (RF) plasma heating is of interest in the following frequency ranges: 50 to 300 MHz and 100 to 300 GHz. In particular, two RF heating methods chosen for near term and future fusion applications are Ion Cyclotron Resonance Heating (ICRH), in the frequency range of 50 to 300 MHz, and Electron Cyclotron Resonance Heating (ECRH), 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 pulse lengths from 30 seconds to continuous operation. Grant applications are sought for the development of (1) antenna systems capable of transmitting 5 MW through a 1/4 square meter port, (2) other components of the system, such as tuning and matching components, feed-through devices, coaxial cables, stub tuners, RF power amplifiers and tubes for ICRH, and mode converters, windows, output couplers, loads, diagnostics to evaluate the performance of such components, and launching systems for ECRH, (3) high voltage, high current power supplies to operate RF sources in three operating ranges: 1 to 2 kV at 10 to 100 kA, 50 to 100 kV at 0.1 to 1 kA, and 500 to 2000 kV at 10 to 20 A, (4) microprocessor controllers for thyristor power supplies, gate-turn-off thyristors, fast acting safety devices for thyristors, and fast-opening breaking switches that can interrupt hundreds of kiloamperes and withstand tens or hundreds of kilovolts, (5) switching power-supplies to replace heretofore used conventional transformer-rectifier systems, and (6) energy extraction systems from spent beams.

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, such as position, shape and current density, will be needed for the control of long-pulse plasmas. In addition, methods are desired for examining the edge plasma region and areas of high heat flux deposition on limiters or divertor plates. Finally, measurement of the properties of auxiliary plasma heating techniques and non-inductive current drive is also desired. Grant applications are sought to develop techniques for measuring these parameters. 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.

c. Particle Detection and Control—In magnetic fusion experiments, particles are injected into the plasma by fueling techniques to improve plasma conditions and undesired particles are removed by vacuum generation processes. For particle control, grant applications are sought to improve the performance of deuterium or tritium pellet injectors and vacuum system components such as pumps, seals, bushings, leak detectors, and ultrahigh vacuum valves. For particle detection, grant applications are sought for systems to (1) detect and characterize particles including ions, electrons, neutrons, and photons subject to radio frequency heating; particles injected by neutral beams; 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 for detector systems 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

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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.

d. Data Analysis, Interpretation of Experiments, 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 methods for the real time control of plasmas by applying control theory techniques, modern hardware, including array processors and massively parallel computers, and software techniques, including modern languages, expert systems, and neural network algorithms. 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.

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40. 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 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 the following materials: (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. For vanadium alloys, areas of interest include increased resistance to degradation under neutron irradiation, relaxation of protection requirements set by their sensitivity to gaseous impurities, and the development of practical arc welding techniques to produce tough, ductile welds. For SiC/SiC composites, improvements in production and 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—Non-structural 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 (0.1 to 1 MW/m^2) for first wall surfaces, long pulse heat fluxes (1 to 10 MW/m^2) on divertor components; and short pulse heat fluxes (10 to 500 MW/m^2) on surfaces that are subjected to plasma disruptions (10^{-3} sec). Grant applications are sought for (1) radiation resistant, high thermal conductivity materials and concepts to control erosion and deposition for limiters, divertors, wall armor, and liners; (2) heat dissipating materials and concepts; and (3) non-silver brazing techniques for graphites, carbon/carbon composites, and beryllium which increase thermal conductance at joints under high thermal loading. For braze joints, nondestructive evaluation techniques need to be developed.

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) thick (15-30 cm) weldable structural case materials with high strength and toughness at 4 K; (6) welding techniques for such thick cryogenic structural materials; and (7) radiation-resistant electrical insulators (e.g., wrapable inorganic insulators

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and low viscosity organic insulators which exhibit low outgassing under irradiation).

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41. TECHNOLOGY, INSTRUMENTATION AND MATERIALS FOR HEAVY ION FUSION ACCELERATORS

The DOE supports a broad research and development program in heavy ion accelerators and associated apparatus. Advanced research and development are needed for (1) new concepts to advance accelerator technology, (2) charged particle beam instrumentation, (3) beam transport techniques, (4) high current ion sources, and (5) low-cost vacuum insulating materials and magnetic core materials. Relevance to applications

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in heavy ion fusion research must be explicitly described. Grant applications that are more appropriate to high energy physics and not specifically related to heavy ion fusion accelerators will be declined. **Grant applications are sought only in the following subtopics:**

a. Advanced Heavy Ion Accelerator Concepts—Grant applications are sought for linear induction accelerator technology that can provide kiloampere ion beams with 1 to 10 kA of pulsed power at 1 to 2 MV at repetition rates from a few Hz up to 200 kHz. Either single or multiple beams in a single unit are of interest. Of particular interest are pulsed power systems based on fast, high current, solid state switching suitable for agile, accurate, programmable pulse shaping, and economical high voltage energy storage systems. These systems should include pulse waveform diagnostics with speed and accuracy comparable to the waveform generators. Methods for efficient energy recovery from rapid-cycling (~100ms) high-field dipole magnets used in beam recirculation schemes are also of interest.

b. Beam Transport, Control and Measurement—Grant applications are sought for (1) cost-effective devices that use electromagnetic, electrostatic, or plasma techniques to manipulate high intensity, high momentum, multiple parallel heavy ion beams; (2) methods for transporting high energy (1 to 10 GeV), heavy (100 to 200+ AMU), short-pulse (10 to 20 ns), high current (1 to 10 kA) ion beams to focal points (<0.5 cm diameter) at a distance of about 5 meters from the final focus element under a range (0.0001 to 10 torr) of reactor chamber vacuum conditions; (3) advanced particle beam diagnostic concepts and devices that provide high speed computer-compatible measurements of particle beam intensity, position, emittance, luminosity, momentum, time of arrival, and energy; and (4) novel, effective techniques to measure the transverse or longitudinal charge distribution in small radius (<5 mm diameter), high current ion beams. Techniques proposed must be nondestructive to the beams being monitored and be less costly than currently used techniques.

c. Ion Sources—Grant applications are sought for particle beam ion sources that have improved intensity, emittance, range of species, and modest (1^+ to 3^+) charge states. In particular, sources for induction linacs are sought that may be laser driven or post-stripped, and that have high current, modest (~10 Hz) repetition rate, and 1 to 20 μs pulse lengths with stable(<1 percent) current amplitude.

d. Materials—Grant applications are sought for low-cost insulating materials, such as ceramic glasses, for high-voltage vacuum feedthroughs and for high voltage accelerating columns greater than 20 inches inside diameter that are capable of having electrodes embedded during the manufacturing process and that also have low outgassing to maintain vacuums less than 10^{-8} torr. These insulators are needed for high voltage hold-off applications in injectors and accelerator modules. Grant applications are also sought for low-cost magnetic core materials with high (dB>2.5T) flux swing and low (<0.10J/kg for Tsat <usec) losses that can be fabricated into compact cores with high (10volts/mil, turn-turn) interlaminar voltage hold-off.

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* See Section 7.1

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