U.S. Department of Energy

Phase I
Technical Topics

FY 2011

Small Business Innovation Research (SBIR) And Small Business Technology Transfer (STTR) Programs

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1. ADVANCED COOLING AND WASTE HEAT RECOVERY TECHNOLOGIES

The Department of Energy is seeking the development of innovative technologies for (1) cooling applications (air conditioning, refrigeration, etc.) in Buildings, Industry, and Transportation that are substantially more energy efficient than today's technologies, cost-competitive with today's systems, and that avoid net direct greenhouse gas (GHG) emissions; and for (2) waste heat recovery in Buildings, Industry, and Transportation applications to generate electricity efficiently and cost-competitively. The focus of these approaches must be on novel innovative technologies; well-known technologies such as mechanical vapor compression cycles or evaporative (water) systems for cooling, or turbines or stirling engines for waste heat recovery will not be considered unless they address some substantial and fundamentally new technological approach. Grant applications will not be considered unless they show a clear pathway to high energy efficiencies (for cooling applications, reduce energy consumption by at least one-third compared to today's systems), are cost-competitive with today's systems, are scalable to small cooling or heat recovery applications (down to a few kW_{th}), and have no net greenhouse gas emissions.

Grant applications submitted in response to this topic must: (1) include a review of the state-of-the-art of the technology and application being targeted; (2) provide a detailed evaluation of the proposed technology and place it in the context of the current state-of-the-art; (3) demonstrate that the proposed technology has a clear pathway to be more energy efficient (for cooling devices, to reduce energy consumption by at least one-third) and have reduced lifecycle costs (high reliability, long lifetimes) compared to current technologies; (4) address a large potential market (for cooling devices, a U.S. savings potential of at least 5% of total U.S. cooling energy consumption); (5) analyze the proposed technology development process, the pathway to commercialization, and the attendant potential public benefits that would accrue; and (6) address the ease of implementation of the new technology, and its ability to be installed with commonly-available skill sets.

Phase I should include (1) a preliminary design, (2) a characterization of laboratory devices using the best measurements available, including a description of the measurement methods, and (3) the preparation of a road map with major milestones, leading to a production model of a system for consideration in Phase II. In Phase II, devices suitable for near-commercial applications must be built and tested, and issues associated with manufacturing the units in large volumes at a competitive price must be addressed.

Grant applications are sought only in the following subtopics:

1a. Advanced Cooling

Refrigeration and air conditioning in buildings, industry, and transportation account for approximately 10 quads of U.S. primary energy consumption. Air conditioning is also a major contributor to electric utility peak loads, which incur high generation costs and generally use inefficient and polluting generation turbines, and peak loads are a major factor in poor grid reliability. Most conventional air conditioners, heat pumps, and refrigerators achieve cooling through a mechanical vapor compression cycle (VCC). However, paths to dramatic improvements in the efficiency of today's VCC systems are likely to significantly increase the price of the equipment. A related problem with today's VCC cooling technology is the adverse environmental impact of the refrigerant gases used. Although the hydrofluorocarbon (HFC) refrigerants used today are relatively safe for the ozone layer, they are strong GHGs. A recent study projected that in 2050, if CO_2 is stabilized at 450 ppm, HFCs would increase radiant greenhouse gas forcing by 28-45 percent above that due to the increase in CO_2 above pre-industrial levels alone (Velders)

This subtopic explores innovative approaches to achieve high efficiencies and net-zero direct GHG emissions in cooling applications. Technologies of interest include electrocaloric, magnetocaloric, thermoacoustic, thermoelectric, thermotunneling, and other novel cycles. Not of interest, however, are technologies such as any type of mechanical vapor compression cycle, water evaporation assisted systems, or absorption cycles unless they address some substantial and fundamentally new technological approach. For each of these approaches to advanced cooling, the technology must meet the above requirements (1-6) to be considered.

Contact: Sam Baldwin, 202-586-0927, Sam.Baldwin@ee.doe.gov

1b. Advanced Waste Heat Recovery

Industry and vehicles, as well as buildings, discharge large quantities of waste heat—typically well over half of the input energy. Larger scale systems, such as bottoming cycles, are available and have been widely used to recapture waste heat for electricity generation in the industry and power sectors. Unfortunately, few options are available at smaller scales (down to a few kW_{th}), not only for use in vehicles but also for some commercial and industrial applications. The recovery of some of this waste heat represents an enormous untapped opportunity.

This subtopic explores innovative approaches to achieve high efficiencies in waste heat recovery and electricity generation at cost-competitive rates with systems that are scalable to small applications (e.g. thermal sources as small as a few kW_{th}). Technologies of interest include thermoelectric and other novel cycles that can be scaled down to small applications.

Contact: Sam Baldwin, 202-586-0927, Sam.Baldwin@ee.doe.gov

1c. Strategies and Technologies for Cost Effective '5 9s' Duct Sealing

This would support research in new, time- and cost- effective technologies and diagnostics for enabling and ensuring cost-effective rapid and reliable sealing of existing and new ductwork and piping. It is estimated that stopping leaks in ductwork alone could increase efficiency of existing buildings by 10% on average. Diagnostic tools and sealing approaches should be applicable to a wide range of new and existing duct and or piping systems. Both improvements in existing technologies such as aerogels, and totally new concepts are encouraged.

Contact: Tina Kaarsberg, 202-287-1393, Tina.Kaarsberg@ee.doe.gov

1d. Ultrathin Pipe and Duct Insulation

This would support research on novel, low cost technologies that take up far less space and/or offer other attributes (e.g. flexibility) that permit their use in tight spaces. These can include the

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use of very thin nano-based insulators. The availability of such insulation would greatly expand the number of building that could be retrofitted cost-effectively.

Contact: Tina Kaarsberg, 202-287-1393, Tina.Kaarsberg@ee.doe.gov

1e. Geoexchange Heat Pump (GHP) Component R&D

This would support research on: variable-speed (VS) components, advanced sensors and controls (including water flow sensing), electronic expansion valves, heat exchange (HX) design and fluids (including nanomaterials and nanofluids which offer the possibility of decreasing thermal losses in conductivity), system optimization, unit control algorithms, and load management tools. This would address the barrier of high initial costs for widespread GHP deployment by improving GHP components to increase efficiency as well as energy savings as compared to conventional systems.

Contact: Tina Kaarsberg, 202-287-1393, Tina.Kaarsberg@ee.doe.gov

1f. Innovative GHP System/Loop Designs

This would support research on innovative system/loop designs that reduce the costs of system and/or loop installation, through new design layouts, system components, materials, and/or methods. This would reduce one of the major costs for GHP technology-- the high cost of drilling and loop installation.

Contact: Tina Kaarsberg, 202-287-1393, Tina.Kaarsberg@ee.doe.gov

1g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Sam Baldwin, 202-586-0927, Sam.Baldwin@ee.doe.gov

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2. PRODUCTION OF BIOENERGY AND BIOFUELS FROM CELLULOSIC AND NON-FOOD BIOMASS

To break the U.S. dependence on imported petroleum for producing various liquid transportation fuels, numerous initiatives for biofuels development are underway. The Energy Independence and Security Act of 2007 (EISA) specifies a target quantity of 36 billion gallons of renewable fuels (Renewable Fuels Standard or RFS) to be annually produced in the U.S. by 2022. Of this amount, 21 billion gallons would come from advanced biofuels; 16 or more billion gallons of the 21 billion gallons is to be provided by cellulosic ethanol and the balance would come from other advanced biofuels.

Biopower is electricity produced from a wide range of biomass resources. The use of biopower is one way to help meet national goals for the use of clean renewable energy (e.g., Renewable Portfolio Standards or RPS). Biomass is a base load renewable energy source that is readily available across the U.S. Biomass offers a renewable energy solution in areas where other renewables are not available.

To achieve these goals, it is essential to ensure that cost competitive feedstocks of appropriate quality for bioenergy production are widely and sustainably available in sufficient quantities. Because the feedstock cost is a major element in the production of bioenergy, research is needed to ensure the cost-effective supply of major biomass resources to biorefineries, so that they can be converted to biofuels, biopower, and bioproducts. This topic seeks the development of technologies to ensure this feedstock supply and includes the production of diesel fuel substitutes via microalgae production, biochemical pathways for the utilization of cellulose and hemicellulose to produce ethanol, and the thermochemical conversion of biomass to liquid transportation fuels such as ethanol, mixed alcohols, and advanced hydrocarbon-compatible and infrastructure-ready biofuels.

Process economic considerations suggest that processing of lignocellulosic materials would occur at large scales in integrated "biorefineries" producing multiple products. Grant applications are sought for new concepts and tools that will stimulate innovation and progress towards the realization of highly efficient and economically viable biorefineries producing liquid fuels, power, and products from lignocellulosic and other non-food biomass.

Grant applications are sought only in the following subtopics:

2a. Biomass Feedstock Stabilization and Drying

A complete biomass feedstock supply system incorporates elements of labor, machinery, and infrastructure to move biomass from the field to the biorefinery. Feedstock moisture affects all supply chain elements: collection, storage, preprocessing, handling, and transportation. Disregard for biomass moisture can increase feedstock supply-logistics costs and result in biomass material instability, which is caused by microbial actions. "Wet" biomass as normally defined has moisture content that is high enough to require actions such as introducing amendments, barriers, etc. to ensure stability. Microbes react more to "water activity" due to the available water contained inside the biomass than to the bulk percentage of moisture in the biomass. An optimum supply system will balance the costs of handling and storing wet biomass against the costs of removing the moisture and preprocessing the material to a uniform handling format (Sokhansanj et al. 2009). Grant applications are sought to develop innovative means of utilizing spontaneous heating generated in biomass in managing moisture content of both herbaceous and woody biomass thereby minimizing external energy input.

Several species of biomass may have high moisture content at the time of harvest. This high moisture limits the length of time the biomass can be stored without spoilage (Wadso, 2007). In some cases spontaneous heating may cause fires (Walker, 1977). However, the spontaneous heating may provide a source of natural heat for drying and prolonged stabilization of biomass if the heat energy is controlled and utilized in innovative ways. This request for proposals seeks applications that prove the feasibility of innovative techniques, amendments, and/or systems that control self heating as a potential means of drying to prolong biomass stability.

Grant applications should be cognizant of the fact that feedstock supply system requirements are highly dependent on feedstock variety. For example, the amount of moisture that can be allowed in the biomass before it becomes aerobically unstable, spontaneously heats-up, and/or substantial damage occurs is feedstock specific. In addition, different feedstock varieties have varying degrees of available nutrients that affect biological stability, spontaneous heating, and potential losses. Proposed studies must quantify biomass losses and/or quality deterioration relative to the benefit of proposed solutions.

Contact: Sam Tagore, 202-586-9210, sam.tagore@ee.doe.gov

2b. Biomass Torrefaction

Improved biomass preparation and handling systems are needed to ensure that reasonable supplies of feedstock will be available for advanced biomass conversion facilities (Prins et al., 2006). These may include biofuels facilities using gasification or pyrolysis as technology pathways, or may potentially include power generation systems where heat and electricity are products. These types of facilities depend in part on economies of scale to be economical, and may consume from a few hundred to a few thousand tons of biomass daily. Since the size of these facilities will require biomass to be delivered from significant distances, it is important to ensure that biomass can be delivered cost effectively.

One potential approach to improving feedstock characteristics is torrefaction (Sadaka and Negi, 2009). Torrefaction is a pyrolytic process that reduces moisture content and increases energy density of biomass and yields a solid uniform product. Torrefaction lowers the O/C and H/C ratio and make it more efficient for gasification and combustion applications (Pentananunt et al., 1990).This process potentially reduces transportation costs and improves the ability to feed biomass to conversion systems (Mitchell et al., 2007). While a great deal of interest has been expressed in torrefaction process over the past 2-3 years, the mass and energy balances for torrefaction systems are poorly characterized, and the impact of these processing losses on the product cost has not been well characterized. This is particularly true in the production of pellets of torrefied material. Converting torrefied biomass to pellets improves the consistency and marketability of the feedstock. The torrefaction process changes the composition of the biomass depending on the degree of torrefaction and will influence how much the hemicellulose has been broken down and this leads to a more hydrophobic material relative to fresh biomass (Bridgeman et al., 2008). While this can be a favorable characteristic in some situations, it also makes the torrefied biomass more difficult to pelletize.

Grant applications are sought for innovative approaches to producing torrefied biomass as uniform pellets. The purpose of the first phase of this work is to establish projected costs of such material based on firm material and energy balance measurements. Proposed approaches must show that torrefied biomass can be pelletized with good physical and proximate and ultimate composition as a uniform feedstock. The work must provide measured mass and energy balances to 95% or greater of the weight of the biomass and must account for external inputs such as electricity, heat, additives, and similar items required for processing. Detail analysis of the volatiles lost and their energy value with respect to torrefaction temperature and residence times should be a part of the mass and energy balance study. The research must demonstrate the technique for at least two types of biomass with significantly different characteristics. Wood and corn stover are examples of two biomass feedstocks with significantly different characteristics. The goal of Phase I will be a clear analysis of the overall costs of providing pellets of torrefied biomass, including all external inputs, to a large-scale biomass facility at a scale of at least 500 dry tons/day.

Contact: Sam Tagore, 202-586-9210, sam.tagore@ee.doe.gov

2c. Sugar Catalysis to Advanced Biofuels and Chemical Intermediates

Grant applications are sought for innovative technologies for conversion of the sugar portions of lignocellulosic biomass to advanced biofuels (non-alcohol, non-FAME) and chemical intermediates.

Catalyst (biological or inorganic in nature) that convert sugars at high rates with high selectivity (minimum byproduct formation) are being considered for biofuels and bioproducts production. Two such examples of ongoing research include a thermo/chemical route to convert sugars to hydrocarbons[1] and a biochemical route to convert sugars to advanced biofuels and chemicals[2]. The ability to develop robust, industrially useful catalysts that are cost effective will require the acquisition of substantial knowledge regarding the fundamental factors that limit efficient sugar bioconversion in hydrolysate. A collective knowledge on catalyst improvement including deeper understanding of catalyst lifetime, catalyst degradation/regeneration, hydrolysate toxicity as well as process considerations are required. Specifically for biological catalysts, a collective knowledge on strain improvement including deeper understanding of strain physiology, metabolic engineering options, hydrolysate toxicity as well as process considerations are required.

Grant applications are sought to determine the technical and economic feasibility of sugar catalysis to biofuels and chemicals. This project shall not include construction of facilities. In each case, applicants must be able to demonstrate the potential for favorable economics of lignocellulosic biomass for the production of advanced biofuels and chemical intermediates. Additionally, the catalyst must be able to function in the presence of hydrolysate inhibitors.

A successful Phase 1 project is expected to lead to a meaningful Phase 2 project.

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Contact: Sam Tagore, 202-586-9210, sam.tagore@ee.doe.gov

2d. Pyrolytic Thermal Depolymerization

Cellulosic biomass is composed primarily of three polymeric building blocks the cellulose, hemicelluloses which are polysaccharides and lignin which is a complex cross linked polymer that has a significant number of aromatic groups. Selective depolymerization of biomass to more readily accessible and often reactive oligomers or monomers would be beneficial to the production of biofuels or bioproducts.

One means to depolymerize biomass is thermal conversion of biomass involving the use of heat to disrupt the structure of biomass and provide intermediate products that can subsequently be converted to desired products. For example, gasification produces syngas composed of hydrogen, carbon monoxide, and other gases that can be catalytically converted to fuels. Likewise, pyrolysis produces a bio-oil intermediate that can be stabilized and upgraded to diesel and other hydrocarbon fuels. While either gasification or pyrolysis systems can be effective at converting a wide range of biomass feedstocks to biofuels, these are unselective processes and do not preserve nor exploit the sometimes desirable characteristics of the polymeric materials in the biomass structure.

Thermal depolymerization is a general approach to converting biomass where the initial thermal treatment preserves desirable characteristics of the biomass feedstock and exploits those for more effective utilization of the resource. For example, effective deplymerization might better use the 6-carbon sugar monomers from cellulose to produce straight-chain hydrocarbon fuels, or more effectively use the phenolic portions of lignin to produce aromatic hydrocarbons.

Grant applications are sought to develop innovative concepts for thermal depolymerization of biomass to hydrocarbon fuels. Phase I efforts should focus on proof of concept experiments that demonstrate the viability of innovative approaches. The concept and the work to be performed must include both the depolymerization and the subsequent conversion of intermediates, if any, to hydrocarbon fuels and/or bioproducts. In particular, the work should clearly demonstrate the technical and economical advantages of the thermal depolymerization as compared to other types of approaches such as gasification or pyrolysis.

Contact: Sam Tagore, 202-586-9210, sam.tagore@ee.doe.gov

2e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Sam Tagore, 202-586-9210, sam.tagore@ee.doe.gov

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3. HYDROGEN AND FUEL CELLS

By enabling the widespread commercialization and near-term use of fuel cell technologies for stationary, portable, and transportation applications, the DOE's Fuel Cell Technologies (FCT) Program, within the Office of Energy Efficiency and Renewable Energy (EERE), works to reduce petroleum use, greenhouse gas (GHG) emissions, and air pollutants, as well as contribute to a more diverse energy supply and efficient use of domestic energy.

Consistent with the President's objectives, The FCT Program will develop multiple fuel cell technologies (including solid-oxide, alkaline, and polymer electrolyte membrane fuel cells) using multiple fuel sources (including diesel, natural gas, bio-derived renewable fuels such as methanol, and fuels derived from other renewable resources). Applications include distributed generation, backup power, auxiliary power units (APUs), portable power systems, material handling equipment, specialty vehicles, and transportation. Distributed generation and backup power systems supported by this activity may be grid-tied or grid-independent, utilize waste heat, operate directly with hydrogen or natural gas, or use reformers to operate with natural gas, bio-derived fuels or coal-derived fuels.

Hydrogen Production and Delivery R&D of the Program encompasses distributed production through renewable liquids reforming and electrolysis, and central production through biomass gasification, wind-powered electrolysis, solar driven high temperature thermochemical cycles, and biological and photoelectrochemical pathways. It also includes the technology for transporting and distributing hydrogen both to and at fueling sites. The Program's Hydrogen Storage R&D portfolio concentrates on low-pressure, materials-based technologies and will also explore advanced conformable and low cost tank technologies for hydrogen storage systems to meet performance targets.

The Safety and Codes and Standards subprogram funds research to provide the technical data on hydrogen technologies (such as fuel cells and hydrogen production, storage, and distribution systems) that are necessary to support and inform the codes and standards development process. Its work includes studies to determine the flammability, reactive, and dispersion properties of hydrogen. It also subjects components, subsystems, and systems to environmental conditions that could result in failure to check design practices and failure-mode prediction analysis. The Early Market Validation subprogram accelerates commercialization of fuel cell power systems. The goal of these activities is to eliminate non-technical barriers and increase opportunities for market expansion. By increasing product demonstration, these early market applications will accelerate development of manufacturing capability and domestic supplier base, and reduce manufacturing costs.

Grant applications are sought only in the following subtopics:

3a. Reducing the Cost of High Pressure Hydrogen Storage Tanks

Inexpensive storage vessels for compressed hydrogen gas are critical to the widespread commercialization of hydrogen fuel cells in early market and light-duty vehicle applications. Currently, the high-pressure (i.e., 350 to 700 bar) storage tanks are constructed using expensive high strength carbon fibers such as T700 to form these gas cylinders [1,2]. Low-cost carbon fiber precursors, tank designs that reduce carbon fiber use, manufacturing processes, and alternative materials such as glass or other inexpensive fibers are all potential solutions to reducing the overall system costs. Before compressed hydrogen gas storage vessel technology can move forward to widespread applications, solutions must be developed to show substantial cost reductions using fibers with mechanical strengths matching or exceeding the properties of aerospace quality carbon fibers (greater than 600 ksi ultimate tensile strength).

Grant applications are sought in two distinct approaches to develop low-cost compressed gas tanks for hydrogen storage but with costs significantly lower than those projected during recent analyses [1,2] for large-scale manufacturing of storage vessels constructed of high strength carbon fibers. Carbon fiber currently contributes as much as 75% to overall tank costs. The goal is to reduce cost of the carbon fiber portion from $28/kg to $15/kg or reduce the amount of carbon fiber used with any of the following approaches:

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Approach 1 solicits R&D that will facilitate cost reduction from new tank designs; reduction of carbon fiber requirements (for examples see [4,5]); and advanced manufacturing technologies such as fiber placement or high speed winding. Approach 2 solicits development of high-strength fibers from less expensive precursors, and using low-cost manufacturing processes (including associated pre-treatments, stabilization (cross-linking), oxidation, carbonization, graphitization, post-treatments, and packaging) or alternative materials such as glass or polymers. The goal is for significantly lower cost fibers that can meet or exceed the performance specifications of today's cylinders manufactured with T700 carbon fibers [1,2].

Phase I for approach 1 should focus on creating complementary strategies based on approaches to develop low-cost high-pressure tanks. The Phase I project should include a detailed technical analysis comparing today's tank technology against the performance of the proposed alternatives, along with an economic analysis that considers all relevant capital and O&M costs involved with tank production and lifecycle costs. The plan should be sufficiently comprehensive that acting on suggested improvements could begin within several months of the phase II award date.

Phase I for approach 2 should focus on identifying inexpensive precursor materials and processing strategies to produce much less expensive fibers for fabricating low-cost high-pressure tanks or reduce the amount of carbon fiber required. The Phase I project should include a detailed technical analysis and cost projection of suggested synthesis methods and fiber production methods to yield the desired high-strength fibers. A plan for follow-up activities in Phase II should be sufficiently comprehensive that laboratory production of prototype quality fibers could begin within several months of the phase II award date.

Phase II for either approach would address development and validation of selected technology advancements that were identified in Phase I. For approach 1, activities would include full-scale development and, when appropriate, building one to three complete high-pressure tanks. For approach 2, Phase II would address fabrication of fibers from the most promising low-cost materials that had been identified and also include characterization of mechanical properties and durability of these fibers during fabrication of high-pressure hydrogen gas cylinders.
The final report will compare the developed tank cost reduction approaches with incumbent technologies for storage vessels made from current high-performance carbon fibers.

Contact: Eric Miller, 202-287-5829, Eric.Miller@ee.doe.gov

3b. Fuel Cell Balance-of-Plant

The HFCIT Program supports R&D efforts aimed at accelerating the deployment of fuel cell technology by reducing the high cost of fuel cell materials, lowering manufacturing costs, and extending fuel cell operating lifetimes. Several years ago, the cost of a fuel cell stack was much higher than the cost of the balance-of-plant (BOP); thus R&D funding focused on reducing the stack cost. Those R&D efforts succeeded in reducing the cost of fuel cell stacks to the point at which their projected high-volume cost is nearly equal to the cost of the rest of the fuel cell system.

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Now, attention is being focused on BOP components. During fuel cell operation, BOP components are often the first to fail; system shutdowns caused by non-stack components reportedly accounting for 85-90% of system failures. More than 68% of all labor hours spent repairing fuel cells are devoted to repairing BOP components. Thus, grant applications are sought for R&D of BOP components, to reduce failure rates, lower costs, and reduce parasitic losses dramatically. BOP components of interest include, but are not restricted to, seals, motors, sensors, water vapor transport exchangers, heat exchangers, valves, pressure transducers, flow meters, pumps, and blowers. Applicants must show that their concepts will lead to components that will cost an appropriate fraction of the total cost target of BOP. (For example, a pump for transportation fuel cell applications should have a projected cost of an appropriate fraction of the 2015 target of $15/kW, assuming a production rate of 500,000 units/yr.) Also, as with the rest of the fuel cell system, BOP components must possess the required durability for the targeted application under appropriate operating conditions and regimes. In particular, components must last more than 5,000 hours under cycling conditions for transportation applications and more than 40,000 hours for stationary applications. The cost targets are $30/kW and $750/kW for transportation and stationary applications, respectively. Grant applications for transportation-related fuel cell systems must demonstrate a capability for successful operation under severe conditions, including power transients, high temperatures, sub-freezing temperatures, and low relative humidity.

Phase I applications should identify, develop, and characterize promising BOP component concepts for PEM fuel cells and small-scale solid oxide fuel cells (e.g., < 10 kW). Phase II should include the development, design, fabrication, and testing of the BOP components. The Phase II deliverables will include the proof-of-concept components along with a demonstration that the components can be integrated into fuel cell systems that meet the DOE cost and durability targets as defined above.

Contact: Nancy Garland, 202-586-5673, Nancy.Garland@ee.doe.gov

3c. Hydrogen Odorant Technology

The human physical response to malodor has played an important role in public safety around flammable gases for over seventy years. Odorants in natural gas are a proven, cost-effective means for leak detection in commercial applications where the desired action upon detection is area evacuation. The challenges for adapting odorant technology to a hydrogen infrastructure are two-fold. The flammability range and high dispersion velocity of hydrogen require an odorant technology to work over a broader set of conditions than for traditional hydrocarbon fuel gases. The sulfur-containing odorants that are used for hydrocarbon fuel gases will not work in fuel cell technology because they adversely affect fuel cell and advanced storage performance.

Grant applications are being sought to develop hydrogen odorant technology that is compatible with the dispersion characteristics of hydrogen and is compatible with fuel cell and storage materials. The odorant chemical must be non-toxic and should be compatible with fuel cell technology (e.g. meet proposed fuel quality performance standards).

Phase I must provide a screening of candidate odorant chemistries that meet the following performance requirements:

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- High dispersion velocity so that a hydrogen release is detectable over the flammability range;
- Stability over the range of pressures and temperatures found in vehicle and stationary fuel cell technology;
- Does not adversely affect fuel cell performance;
- Provides an olfactory response for tolerable odorant loadings;
- Meets life cycle cost goals.

A Phase II project would address durability of fuel cell systems and components (including fuel storage and delivery components) and develop the full set of technical information for fuel quality standards.

Contact: Antonio Ruiz, 202-586-0729, antonio.ruiz@ee.doe.gov

3d. Demonstration of Alternative-Fuel Fuel Cells as Range Extenders for Battery-Powered Airport Ground Support Equipment (GSE)

This SBIR topic is focused on airport ground support equipment (GSE). The Battelle Memorial Institute study, "Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets," indicates that the airport GSE has the potential to provide significant lifecycle cost savings over lead acid battery and combustion engine systems under certain types of operation [1].

The airport GSE market includes various types of specialty vehicles used to service aircraft during ground operations. GSE commonly used in airport operations include baggage tractors (or ground support "tugs") used to tow baggage trailers between the aircraft and terminal, and aircraft pushback tractors that push aircraft back from the terminal to the taxiway or tow aircraft to and from the hangar for maintenance. Battery-powered tugs usually handle baggage and cargo or tow lower-weight aircraft (for small regional airline operations). They use wet cell or sealed gel cell lead-acid batteries; typical capacity ranges from 2.5 HP/1.9 kW (36V motor) to 100 HP/75 kW. ICE-powered tugs typically use 4-cylinder or 6-cylinder engines fueled with diesel, gasoline, liquefied petroleum gas (LPG or propane), compressed natural gas (CNG), or Jet A fuel. The capacities of diesel and gasoline engines in airport tugs vary widely, ranging from 25 HP/19 kW to 300 HP/224 kW.

The DOE considers the deficiencies of both battery-powered systems and PEM fuel cell systems could be mitigated by the use of an alternative-fuel fuel cell as a range extender for battery-powered airport GSEs. Accordingly, DOE is interested in demonstrating alternative-fuel (direct methanol, direct ethanol, biofuel, etc.) fuel cell technologies that also feature the potential for radical improvements in fuel cell-powered GSE performance, durability, cost, fueling infrastructure, and/or manufacturing efficiencies. The primary thrust of this Topic is the deployment of alternative-fuel fuel cell technologies and fueling infrastructures, both of which use methanol fuels reformed from renewable sources, such as biomass (wood, wood wastes, grass, agricultural crops and by-products, etc.) and municipal waste, in order to mitigate greenhouse gas emissions.

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Applications for Phase I awards should clearly describe the potential benefits of the proposed alternative-fuel fuel cell technology in terms of durability, cost, and performance, compared to internal combustion engine and battery-powered systems. The application should clearly state the status of the applicant's current stack and/or component technology as it relates to the state-of-the-art, include energy efficiency, power density, and cost.

DOE seeks proposals using packaged solutions for 5 to 20kW alternative-fuel fuel cell systems, capable of powering an airport baggage handler or comparable GSE vehicle for (at a minimum) 10 hours of continuous operation and 5,000 total hours. Projects are sought to fill GSE demand at target markets: commercial airports operating multiple shifts per day.

Applications should describe at a minimum –

- A complete fuel cell power system designed for powering airport GSE;
- GSE equipment retrofit specifications (as applicable);
- Technical requirements for fuel cell stacks, balance of plant, thermal management, and power electronics;
- The fuel storage and dispensing system including installation, commissioning, maintenance, and decommissioning capable of supporting the GSE fill requirements for the specified operations (system shall be capable of safely dispensing fuel into the proposed GSE);
- Weather shelter for dispensing operations; and
- A plan for obtaining all necessary government approvals and permits for all aspects of the dispensing system.

The cost of the GSE equipment, excluding the fuel cell power system, is the responsibility of the applicant and should be addressed included as part of the application.

Expected Outcomes:

- Phase I
  - Explore feasibility of concept and report on the phase I objective stated in the sections above and detailing objectives, milestones and deliverables for Phase II.
- Phase II
  - 5 to 20 kW fuel cell systems delivered, installed on GSE equipment, and field tested at a specified site.
  - Performance report documenting results from operating proposed system during field testing. Report should include any safety or performance data and issues identified during the operation of the units during field testing.

Contact: Peter Devlin, 202-586-4905, Peter.devlin@ee.doe.gov

3e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Rick Farmer, 202-586-1623, Richard.farmer@ee.doe.gov

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4. ENERGY SAVING TECHNOLOGIES FOR COMMODITY MANUFACTURING INDUSTRIES

Industries consume more energy than any other sector within the US energy economy – including residential and commercial building energy use and the transportation sector.

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The manufacture of commodity materials – such as basic metals, chemicals, paper, and glass (along with the forming of these materials into basic shapes, such as casting primary metals, plate glass manufacture, shape forming of steel to I-beams or rolls, etc) – consumes more than 70% of all energy consumed by industrial manufacturing in the U.S.

This topic seeks research and development for new energy savings technologies to be applied in U.S. manufacturing operations, in order to enhance U.S. industrial competitiveness. Applicants must identify the industry and process in which the proposed technology will be applied; approaches that address more than one industrial process or manufacturing sector are most welcome. The proposed technology must be innovative or at least new to the proposed industrial application, demonstrate that the approach will overcome barriers to energy efficiency faced by manufacturers, and provide a reasonable estimate of how much energy (and the form of the energy) can be saved. Grant applications for development of entirely new industrial processes to replace existing processes, or for the development of new commodity materials, are not of interest and will be declined. However, grant applications for the development of new process equipment will be considered responsive, provided that the equipment is needed to complete the feasibility investigation under Phase I.

Potential applicants are strongly encouraged to develop partnerships with a U.S.-based (of primary U.S. ownership) industrial company, especially one that can support a follow-on commercialization effort. Although new energy savings technologies leading to potential overseas markets are of interest, the R&D must be directed toward industrial processes as they are applied in the United States.

Grant applications are sought only in the following subtopics:

4a. Sensors and Controls

Grant applications are sought to develop sensors and controls for existing material manufacturing processes. Of all enhancement options available, sensors and controls provide a sizeable opportunity for process efficiency enhancement. Areas of interest include, but are not limited to, process sensors and their associated controls for (1) *in situ* process measurement, especially for high-temperature or other harsh environment processes and (2) chemical and petroleum processing methods that do *not* rely on expensive analytical instrumentation. Proposed approaches must culminate in the development and commercialization of new sensor and control systems to be applied in manufacturing processes used in the U.S. Once the new sensor concept is demonstrated, the applicant would be expected to work with appropriate Government agencies to ensure that the new technology will meet any regulatory bounds for commercialization. However, proposed investigations involving regulatory aspects of new process sensors and controls are not of interest and will be declined.

Contact: Bhima Sastri, 202-586-2561, Bhima.Sastri@ee.doe.gov

4b. Low Temperature Waste Heat Recovery

Grant applications are sought to advance materials design to augment energy recovery from low temperature waste heat. Energy intensive industrial processes (steel, aluminum, glass, etc..)

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discharge large quantities of high temperature waste heat, and there exists adequate technology to convert it to usable electricity. However, few options exist for efficient and effective energy recovery from low temperature waste heat (temperatures below 130 °C) as generated in many smaller scales industrial processes. The use of thermoelectric technology represents an opportunity for energy recovery in such low temperature operations. To fully realize this, development of different thermoelectric and module materials and the corresponding thermal management strategies will be required. Applications are sought to develop: (1) new thermoelectric materials for low temperature waste heat recovery and electricity generation that have a high figure of merit (ZT) and the potential for large-scale production, at costs competitive with conventional technologies considering the full system over its lifetime; and (2) thermoelectric systems that address all of the thermal interface, materials compatibility, and thermal management issues of the integrated system. Proposals that address all of the above subjects are preferred.

Contact: Bhima Sastri, 202-586-2561, Bhima.Sastri@ee.doe.gov

4c. Advanced Materials

Advances in materials science and engineering are likely to be key enablers for many energy efficiency and carbon reduction solutions. They could revolutionize the way energy is produced and/or consumed in the industrial setting. As such, grant applications are sought to further develop the manufacturability of or capabilities/properties of certain types advanced materials in the energy space; priority will be given to applications that carefully examine the achieved efficiency with the proposed improvements. Topic areas of interest in this solicitation include one or more from the following: (1) Functional materials including coatings, thin films, or catalysts: These types of materials interact with the environments they are situated in. Improvements could result in better system durability/ reliability and/or accelerated reactions/conversions, all of which could augment energy efficiencies. (2) Engineered polymers (EPs): Because of their high strength-to-weight ratios, these materials are often used as substitutes for structural members in various applications in the aerospace markets. Lighter aircrafts and spacecrafts result in reduced fuel consumption. The high cost for fabricating these EPs make them cost prohibitive for wide spread commercial use. Manufacturing processes that could significantly reduce the cost of EPs would allow them to be integrated into many new applications such as in vehicles, thereby imparting similar efficiency gains as observed with their use in the aerospace sector. (3) Strengthened glass: Glass produced today achieves only 0.5% of its ultimate lab-tested strength, requiring overbuilt product designs and limiting potential applications of this versatile, recyclable material. If new technologies could be developed to improve the strength of glass, a host of advantages could be realized including new lightweight products that will require less energy use in manufacturing and transportation. Strengthened glass could be integrated into more renewable energy and energy-efficient applications such as solar panels, high-efficiency "smart" windows, and lightweighted glass container.

Contact: Bhima Sastri, 202-586-2561, Bhima.Sastri@ee.doe.gov

4d. Sustainable Remanufacturing Technology

Opportunities in reducing energy consumption and lowering emissions associated with product life cycles can be obtained through improvements in remanufacturing technology.

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Manufacturing waste equals 59% of landfill waste [1]. Remanufacturing involves cleaning, repairing, and restoring to working condition. Grant applications are sought for new remanufacturing technologies to significantly improve energy and environmental performance in manufacturing industries.

Grant applications should: (1) demonstrate that the proposed approach will help reduce emissions and improve efficiency, and have limited or no negative impact on overall capital costs; and (2) include an economic analysis that accounts for long-term implications.

Contact: Bhima Sastri, 202-586-2561, Bhima.Sastri@ee.doe.gov

4e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Bhima Sastri, 202-586-2561, Bhima.Sastri@ee.doe.gov

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5. INNOVATIVE SOLAR POWER: LOWERING THE COST OF NOVEL PHOTOVOLTAICS, SOLAR DESIGNS FOR DESALINATION, AND DISTRIBUTED CONCENTRATING SOLAR POWER

U.S. Department of Energy Solar Energy Technologies Program goals are to reduce the cost of electricity from solar to be competitive with retail and wholesale electricity market rates. It is projected that by 2015 retail electricity (residential and commercial rates) will range from $0.06 to $0.15/kWh, and wholesale electricity will be $0.04 to $0.08/kWh. Solar energy must be at or below these costs if it is going to play a major role in the broader electricity market, though other markets may also be a possibility for targeted solar plays. In order to fulfill its overall mission to bring cost competitive solar electricity to the United States while also providing opportunities for more specific applications of solar technology development, projects are solicited for innovative solar technologies for High Efficiency, Low Cost Thin Film Photovoltaics; Low Cost Building Integrated Photovoltaics; Static Module PV Concentrators; Solar-Powered Water Desalination; Distributed Concentrating Solar Power; and Other Innovative Solar Technology Concepts.

Grant applications submitted in response to this topic should (1) include a review of the state-of-the-art of the technology and application being targeted; (2) provide a detailed evaluation of the proposed technology and place it in the context of the current state-of-the-art; (3) analyze the proposed technology development process, the pathway to commercialization, and the attendant potential public benefits that would accrue; (4) address the ease of implementation of the new technology, and its potential for high reliability; and (5) demonstrate that the proposed technology has the potential to reduce lifecycle costs compared to current technologies, will have high reliability, and will address a large potential market.

Phase I should include (1) a preliminary design; (2) a characterization of laboratory-scale devices using the best measurements available, including a description of the measurement methods; and (3) a road map with major milestones, leading to a production model of a system that would be built in Phase II. In Phase II, devices suitable for near-commercial applications must be built and tested, and issues associated with manufacturing the units in large volumes at a competitive price must be addressed.

5a. High Efficiency, Low Cost Thin Film Photovoltaics

The highest efficiency photovoltaic devices today currently encompass very small areas and are very expensive, as high as $1,000/m2. Laboratory champion cells have been demonstrated to achieve about 42 % for a three-junction, lattice-matched GaInP/GaInAs/Ge cell. Thin film photovoltaics have demonstrated much lower manufacturing costs but production efficiencies remain significantly lower than their laboratory demonstrations. Typical production module efficiency of about 12 % for CIGS and 11% for CdTe have been achieved and is lower than laboratory results of about 20% for thin film single junction CIGS cells, and about 16.5% for thin film single junction CdTe cells. Grant applications are sought for development of multi-junction thin films with higher efficiencies than current thin films without concentration or tracking.

Contact: Minh Le, 202-287-1372, Minh.Le@ee.doe.gov

5b. Low Cost Building Integrated Photovoltaics

Integrating photovoltaics into building structures opens the door to numerous new energy conversion design possibilities, from curved form factors for aesthetics, PV surfaces that can flex with underlying structures or photovoltaics that fit odd spaces. Innovative low cost Building Integrated Photovoltaic solutions are sought to replace current building materials and structures with products that both replace the old material or structure and add photovoltaic generation. In order to qualify as “low cost”, the photovoltaic product needs to be equal or less than the cost of the material or structure it is replacing.

Contact: Alec Bulawka, 202-586-5633, Alec.Bulawka@ee.doe.gov

5c. Static Module PV Concentrators

Like high ratio tracking PV concentrators, the promise is to reduce cost by replacing expensive PV cells with inexpensive reflectors. Unlike tracking concentrators, static modules have little or no tracking cost, reduced tolerances and lower thermal stress due to lower concentrating ratios. Compared to tracking concentrators, static modules are simple and easy to deploy and maintain. Since the 1970s there have been many R&D efforts, some as simple as positioning flat reflectors to augment the light striking conventional monofacial PV panels. Results have been mixed and designs somewhat complex, nevertheless the promise remains. Grant applications are sought for innovative static module PV concentrators that will significantly impact the cost.

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Contact: Alec Bulawka, 202-586-5633, Alec.Bulawka@ee.doe.gov

5d. Solar-Powered Water Desalination

Only 2.5% of all water in the world is fresh; of that, less than 0.1% is readily available for direct human use. Thus, the need for water desalination is more than evident. A handful of energy-intensive techniques are currently used, mostly at industrial scale; however, solar energy can be used as an alternative to conventional sources of energy for water desalination purposes. Furthermore, many regions that lack potable water happen to have an abundant and plentiful solar resource. Three desalination techniques in particular--reverse osmosis (RO), multi-stage flash (MSF), and multi-effect distillation (MED)--are well-suited to using renewable energy, namely solar energy. RO is the most widely deployed desalination technique, and filters water using a membrane to remove particulates. RO is best suited for brackish water as opposed to saltwater, and plants can range from quite small (a single village) to industrial scale. The only major energy requirement is the pressurization of the feed water, along with any associated pumping. Due to the relatively small size of RO plants and the electricity-only requirement, PV represents the most applicable solar technology for RO. MSF pressurizes and heats seawater, which is then discharged into a low-pressure chamber. The resultant steam loses its brine droplets and condenses into fresh water, which is collected. MSF plants require heat for creating the steam and electricity for pumping. MED is similar to MSF, but rather than a single low-pressure chamber, a series of chambers are utilized, each with a lower pressure than the preceding chamber. Like MSF, it requires both thermal and electrical energy, but MSF has the added benefit of being able to operate at a lower top brine water temperature. Due to the industrial scale and the electricity and heat requirements, CSP represents the most applicable solar technology for MSF and MED. In fact, many MSF and MED plants are built alongside combined cycle plants to take advantage of the heat processes and generated electricity. Grant applications are sought for innovative and cost-effective PV-RO, CSP-MSF, or CSP-MED applications. Although these three options seem to be the most apparent combinations, other solar-powered water desalination alternatives will also be considered. Economic studies have shown that implementing a solar-only water desalination facility is currently three to four times more expensive than with a gas-fired plant; due to lower capacity factors from renewable technologies, a renewables-only desalination plant is inherently limited by the capacity factor of its energy sources. One of the challenges will be making solar-powered water desalination cost-effective; therefore, solar-gas hybrid designs will also be considered. Systems can be desalination-only or co-generation of electricity and fresh water. A preliminary cost analysis should be submitted with the grant application to indicate a commercially viable project.

Contact: Alec Bulawka, 202-586-5633, Alec.Bulawka@ee.doe.gov

5e. Distributed Concentrating Solar Power (CSP)

The overarching goals of the DOE CSP subprogram are inextricably linked to the intermediate and base load power markets. However, because CSP facilities are often located long distances from load centers in remote desert regions, construction of utility-scale CSP power plants are often hindered by a lack of transmission access. Many existing transmission lines are at or near full capacity, and new transmission lines can take years to develop and construct. Other issues, including land permitting and environmental studies (land, water, wildlife, etc.), can further

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complicate, and delay the process of building large-scale CSP facilities. Thus, there is value in exploring the potential of deploying CSP in the distributed market. One of the benefits of distributed CSP systems is the ability to create small-scale, fully packaged, "off-the-shelf" CSP solutions that have the potential to significantly reduce assembly and installation time. Grant applications are sought for innovative and cost-effective CSP systems for distributed applications. "Distributed" is here loosely defined, and can include residential, community, and commercial applications ranging from a few kilowatts to several megawatts. Although dish-engine systems seem to be the CSP technology best suited for distributed applications due to their independent, stand-alone, scalable design, any CSP technology--parabolic trough, linear Fresnel, power tower, dish-engine, or alternative concepts--will be considered. Regardless of the technology utilized, one of the challenges will be making distributed CSP cost-effective, as PV currently represents a more economically attractive solar option in the distributed generation market. Part of the solution may reside in targeting non-electricity distributed CSP applications, including process heating and solar air conditioning; thus, grant applications need not be power-generation based. Systems can be rooftop-mounted or ground-mounted, and can be located close to urban centers or be utilized for rural electrification. A preliminary cost analysis should be submitted with the grant application to indicate a commercially viable project.

Contact: Alec Bulawka, 202-586-5633, Alec.Bulawka@ee.doe.gov

5f. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Alec Bulawka, 202-586-5633, Alec.Bulawka@ee.doe.gov

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6. ADVANCED WATER POWER TECHNOLOGY DEVELOPMENT

The mission of DOE's Water Power Program is to undertake the necessary research, development, test, evaluation, and demonstration of innovative water power technologies, in order to effectively generate renewable, environmentally responsible, and cost-effective electricity from water resources. These technologies include devices capable of extracting electrical power from waves, tides, currents, and ocean thermal temperature differences. They also include technology improvements that will enable cost-competitive development of new hydropower resources such as hydropower projects built on conduit or water conveyance systems, existing non-powered dams, or pumped storage projects, or lead to improvements in the efficiency and/or environmental performance of existing hydropower and pumped storage facilities.

This topic seeks to further advance the development and introduction of novel technologies and solutions that will speed the commercialization of innovative water power systems, thus adding to our nation's renewable energy portfolio. Grant applications must (1) thoroughly describe the proposed system, subsystem, or component, and its potential benefits over current technologies; (2) to the extent feasible, demonstrate that the proposed approach, in a mature configuration, will have a net positive impact on the generation of electricity from water power resources or overall cost of energy (COE) production through improved performance, or reliability, taking into account such long-term factors as operations, maintenance, refurbishment, replacement, and recycling; and (3) establish a clear, realistic long-term plan for concept development, prototype fabrication, testing, and establishing the industry partnerships required for successful commercialization. Proposed projects that involve the participation of a DOE national laboratory must obtain approval from the laboratory prior to submission, and provide evidence of that approval in the grant application.

Grant applications are sought in the following subtopics:

6a. Pumped Storage Hydropower (PSH)

Like conventional hydropower, PSH uses the potential energy of water from an elevated reservoir to generate power. However, PSH uses reversible turbines that can also pump water back into the upper reservoir during low power demand for later use to generate power during peak demand. PSH projects can be cycled on or ramped up and down extremely quickly for peaking power compared to fossil-fueled plants that require significantly more start-up time. Additionally, PSH are used for load balancing, load-following, and other grid management techniques, and enable the large-scale incorporation of variable renewables such as wind and solar.

Grant applications are sought to pursue new and innovative approaches, and/or advances for PSH systems or subsystems, especially those that have combined energy efficiency and environmental benefits. Sample topics include:

- Reversible turbine/generator assemblies (with a focus on cavitation, pitting and vortex prevention, flow induced vibration and fluid structure coupling). Typically intakes and outlets are designed for flow in one direction, but for PSH power intakes need to work as pump outlets and vice-versa.

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- Technologies to more efficiently transport water between reservoirs, to include the design and control of transients in pressurized shafts and tunnels in both directions.
- Application/optimization of underground structures including powerhouses, water conveyance systems and underground reservoirs
- Applications that address other topics that advance the state-of-the-art of pumped storage hydropower technologies will be considered.

Grant applications must provide:
(1) a technical integrated operational description of a proposed PSH system or subsystem;
(2) a description of how the proposed subsystem integrates into an overall project concept and improves on existing technology;
(3) an analysis for determining critical design load cases for the overall concept;
(4) an analysis of the power performance and energy extraction capability based on available energy; and
(5) a discussion considering the environmental issues to be encountered or resolved as a result of the technology employed.

(Subsystems may be proposed that do not address a specific device under development if it can be clearly shown that the subsystems can benefit multiple devices under development generically. In these cases, items 3 and 4 above may not be applicable).

The Phase I report for proposed PSH systems should:
(1) analyze the comparative benefits of the proposed technology relative to what already exists;
(2) summarize and detail the analysis methodology; and
(3) provide results with respect to cost, performance, reliability, production, external conditions, and operating load responses for particular design load cases, in order to demonstrate the overall performance of the full system.

Technologies of interest for PHS that are also more broadly applicable to other types of advanced hydropower systems are separately identified in Subtopic 6-b.

Contact: Rajesh Dham, 202-287-6675, Rajesh.Dham@ee.doe.gov

6b. Advanced Hydropower Systems

Advanced hydropower systems are technologies that improve the energy efficiency and/or environmental performance of existing hydropower turbines, generators, dams, and diversions, including those that increase the water-use efficiency of hydropower projects (i.e., generate more electricity with less water). For the purpose of this solicitation, advanced systems also include new technologies that will enable cost-competitive development of new hydropower resources, such as hydropower projects built on existing water conveyance systems, existing non-powered dams, or scalable pumped storage projects (i.e., lower flows, heads, or capacity). Some new turbine designs have been proposed recently (e.g., fish friendly designs supported by DOE's Advanced Hydropower Systems Program), but few have been fully tested. Also, automated control technologies and decision support systems, which may offer substantial increases in operational efficiencies along with environmental benefits, have been proposed.

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Grant applications are sought to pursue new advances for hydropower systems or subsystems, especially those that have combined energy and environmental benefits. Areas of interest include:

- Advanced electrical components for integration of hydropower with other renewables
- Fish-friendly turbine designs
- Variable-speed or high-voltage generators, especially those applicable to innovative and scalable pumped storage projects
- Cost-effective turbine control systems and flow measurement systems, especially those that can be used remotely or in difficult to access flow paths
- Advanced weirs for flow re-regulation and aeration downstream of power plants
- High-performance materials and coatings to replace or rehabilitate existing components
- Applications that address other topics that advance the state-of-the-art of hydropower technologies will be considered.

Grant applications must provide:
(1) a technical and integrated operational description of a proposed hydropower system or subsystem;
(2) a description of how the proposed subsystem integrates into an overall project concept and improves on existing technology;
(3) an analysis for determining critical design load cases for the overall concept;
(4) an analysis of the power performance and energy extraction capability based on available energy; and
(5) a discussion considering the environmental impact issues to be encountered or resolved as a result of the technology employed.

Subsystems may be proposed that do not address a specific device under development if it can be clearly shown that the subsystems can benefit multiple devices under development generically. In these cases, items 3 and 4 above may not be applicable.

The Phase I report for proposed advanced hydropower systems should
(1) analyze the comparative benefits of the proposed technology relative to what already exists within the hydropower industry;
(2) summarize and detail the analysis methodology that will be applied to the proposed new technology; and
(3) provide results with respect to cost, performance, reliability, production, external conditions, and operating load responses for particular design load cases, in order to demonstrate the expected, overall performance of the full system.

Contact: Rajesh Dham, 202-287-6675, Rajesh.Dham@ee.doe.gov

6c. Wave and Current Energy Technologies

Wave and current energy technologies have significant potential for utility-scale energy production. While many systems are under development and progress is being made towards deployment, new concepts and further refinement of systems, subsystems and components are needed to achieve cost-competitive, reliable and energy efficient devices that meet DOE strategic goals.

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Grant applications are sought to develop approaches that can advance wave and current energy technologies. Areas of interest include wave energy converters (such as point absorbers, oscillating water column devices, overtopping devices, and attenuators), and energy conversion technologies for tidal, river, and ocean currents (e.g., both axial flow and cross flow turbines are of interest, as well as other methods that can demonstrate reasonable energy conversion efficiency).

In addition, computational methods addressing the design of systems and components are needed to optimize energy extraction, conversion, and distribution. These methods may be in the form of modeling techniques, new code development, customization of existing software to apply to the marine energy industry, or the reduction and analysis of computational and empirical results. Grant applications are sought to pursue detailed development of new system concepts, sub systems, or components embodied in a broader concept or device, or design methods to assist the optimization of new systems, subsystems or components. Sample topics include:

- Moorings, seabed attachments and associated arrangements for wave, tidal and/or current devices and/or arrays: including but not limited to the development of: innovative mooring and seabed attachment solutions; design tools for mooring arrays; advanced installation or service equipment; and/or systems/solutions that enhance environmental acceptance
- Advanced Mechanical Sub-Systems/Components: This area is aimed at increasing the mechanical energy conversion efficiency, environmental performance, survivability and/or reliability of devices, including but not limited to: turbine blades, rotors or rotor subcomponents; power conversion mechanisms; low friction bearings with high load capability, long life and high tolerance of variable device geometry; mechanical shaft seals with long life in sea water; and the development and/or application of alternative materials/coatings.
- Advanced Electrical Sub-Systems/Components: This area is aimed at increasing the efficiency and reliability of electrical energy generation, transmission, and distribution, including but not limited to: the design and installation of advanced generator concepts and power electronic converters, optimized device/array power transmission and conditioning systems, low-cost flexible submerged electrical cables, load mitigation systems, and intelligent condition monitoring systems.
- Fluid-structure interaction modeling and/or computational analysis based on first principle physics, to better understand the performance of the hydrodynamic interface of new devices and to enable iterative resolution of various device configurations and ocean resource conditions.

In addition, subsystems, components and design methods that do not address a specific device also may be proposed, provided that it is clearly shown that the proposed component, subsystem or method generically can benefit multiple devices. In these cases, items (2) and (3) below may not be applicable.

Grant applications must provide: (1) a technical and operational description of the proposed device or subsystem (the latter describing how the proposed subsystem integrates into, and enhances, a full energy conversion system); (2) a demonstrated understanding of the design criteria for extreme load conditions and associated load shedding capabilities of the proposed device, or component/subsystem and, if appropriate, the integrated system; (3) an analysis of the power performance and energy extraction capability of the proposed device or component/subsystem and/or the integrated system, as appropriate, based on available energy; and (4) a discussion that addresses the environmental impact issues to be encountered or resolved as a result of the technology employed.

The Phase I report for proposed advanced wave and current energy technologies should
(1) analyze the comparative benefits of the proposed technology relative to what already exists within the industry;
(2) summarize and detail the analysis methodology that will be applied to the proposed new technology; and
(3) provide results with respect to cost, performance, reliability, production, external conditions, and operating load responses for particular design load cases, in order to demonstrate the expected, overall performance of the full system.

Contact: Rajesh Dham, 202-287-6675, Rajesh.Dham@ee.doe.gov

6d. Advanced Component Designs for Ocean Thermal Energy Conversion Systems (OTEC)

OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power. The oceans are thus a vast renewable resource. Technological challenges to OTEC commercialization include: access to and transport of cold seawater from depth, low thermal conversion rates due to relatively small temperature differences between cold deep seawater and warm surface waters; cost and reliability of heat exchanger systems, high capital costs associated with the large scale of conversion equipment; power transmission to shore based facilities; platform design and mooring in deepwater applications; and computational models and analysis methods to assist in the design of OTEC systems, subsystems, and components.

Grant applications are sought for research and development to explore advanced concepts, systems, and/or approaches to address these challenges, in the following areas:

- OTEC Cold Water Pipe (CWP)
- High performance, OTEC-optimized heat exchanger design and manufacture
- OTEC Platforms (to include mooring and power transmission solutions)
- Balance of Plant Components, such as: high volume, high efficiency sea water pumps; high efficiency, low temperature and pressure ammonia gas turbines; and/or high efficiency vacuum pumps.
- Design techniques and methods to provide reliable, affordable iterations toward optimal system configuration and operation.

Grant applications must provide: (1) a technical and integrated operational description of the proposed OTEC component / subsystem; (2) a discussion detailing the benefits (cost, performance, etc.) of the proposed component / subsystem, to include a comparison with

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currently available technologies and/or systems, (3) an analysis that considers the long-term performance and life cycle cost associated with operations and maintenance, refurbishment, replacement, and/or recycling, as relevant; and (4) a discussion considering the environmental issues to be encountered or resolved as a result of the technology employed.

The Phase I report for proposed OTEC systems should:
(1) analyze the comparative benefits of the proposed technology relative to what already exists within the industry;
(2) summarize and detail the analysis methodology that will be applied to the proposed new technology; and
(3) provide results with respect to cost, performance, reliability, production, external conditions, and operating load responses for particular design load cases, in order to demonstrate the expected, overall performance and benefits of the full system.

Contact: Rajesh Dham, 202-287-6675, Rajesh.Dham@ee.doe.gov

6e. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Rajesh Dham, 202-287-6675, Rajesh.Dham@ee.doe.gov

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7. WIND ENERGY TECHNOLOGY DEVELOPMENT

In July 2008, the U.S. Department of Energy (DOE) published the results of a report entitled 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply. According to the report, the United States has more than 8,000 gigawatts (GW) of available land-based wind resources that could be captured economically. Offshore-based wind resources also hold great potential for future development. Under the 20% wind energy scenario, the industry could support 500,000 jobs by 2030, 180,000 of which would be directly related to the industry through construction, operations, and manufacturing.

Although achieving 20% wind energy would have significant economic, environmental, and energy security benefits, the industry must overcome significant challenges to make this goal a reality. In particular, the transmission infrastructure must be enhanced, U.S. manufacturing capacity must be increased, siting, permitting and environmental risks must be reduced, commercial and technical barriers must be overcome, and the reliability and operability of wind systems must be improved. To address these challenges, the DOE Wind Program and the national laboratories collaborate with federal, state, industry, and stakeholder organizations to lead wind-energy technology research, development, and application efforts.

This topic seeks to further advance the development of technologies to speed the commercialization of wind energy as a national resource. Grant applications must (1) thoroughly describe the proposed product, subsystem, or component and its potential benefits over current technologies; (2) to the extent feasible, demonstrate that the proposed approach, in a mature configuration, will have a net positive impact on wind turbine or overall wind plant cost of energy (COE) through performance enhancement or reliability, taking into account such long-term factors as maintenance, refurbishment, replacement, and recycling; and (3) establish a clear, realistic long-term plan for concept development, prototype fabrication, testing, and establishing the industry partnerships required for successful commercialization. Proposed projects that involve the participation of a DOE national laboratory must obtain approval from the laboratory prior to submission, and provide evidence of approval in the grant application.

Grant applications are sought in the following subtopics:

7a. Transportation and Assembly of Extremely Large Wind Turbine Components for Land-Based Wind Turbines

As land-based, utility-scale wind turbines continue to increase in MW rating, transportation of extremely large wind turbine components is becoming a challenge; in fact, it may not be possible to construct wind turbines on land much larger than 3 MW due to constraints such as the

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transportation of blades greater than 50m in length, tower sections and drivetrain components that are too large and heavy to be moved via truck, etc. Grant applications are sought to address the transportation of extremely large wind turbine components through innovative ideas related to transportation solutions, on-site assembly, modular component manufacturing, and/or other related technologies. Grant applications must: (1) demonstrate that the proposed technology would facilitate the deployment of 5+ MW land-based wind turbines, given their extremely large wind turbine components such as blades, hubs, towers, drivetrains, and nacelle assemblies; and (2) demonstrate the economic viability of the technology.

Contact: Ronald Harris, 202-287-6483, ronald.harris@ee.doe.gov

7b. Highly Automated, Utility-Scale Blade Manufacturing

Blade reliability is a large component of operation and maintenance (O&M) costs for wind farm owners/operators. Defects introduced during the manufacturing process are one of the major reliability problems facing the wind industry and can require extensive repair in the field or lead to catastrophic failures. A high-throughput, highly automated process for manufacturing wind turbine blades has the potential to increase blade uniformity and to reduce the total number of defects, thereby greatly enhancing blade reliability. Grant applications must: (1) demonstrate that the proposed technology would allow for a high-throughput, highly automated blade manufacturing process that would significantly increase the uniformity of wind turbine blades and significantly reduce the number and severity of manufacturing induced defects; and (2) demonstrate the economic viability of the technology.

Contact: Michael Derby, 202-586-6830, michael.derby@ee.doe.gov

7c. Wind Energy Capture in Non-Conventional Wind Resources

Conventional wind turbines, both on- and off-shore, are sited in locations where it is possible to erect free-standing towers up to 65 meters in height or more. There are other applications which may not lend themselves to conventional wind turbine technology, including high-altitude wind resources, remote geographic locations, rapidly deployable / temporary systems for disaster relief or military deployment, etc. Grant applications are sought to develop technologies that overcome these barriers to conventional wind deployment, whether through airborne wind energy capture or other innovative designs. Grant applications must: (1) demonstrate that the proposed technology would address barriers to conventional technology related to extracting wind energy in difficult to access wind resources; and (2) demonstrate the economic viability of the technology.

Contact: Mark Higgins, 202-287-5213, mark.higgins@ee.doe.gov

7d. Remote Wind Sensor and Algorithm Development for Offshore Wind

For a large number of offshore energy sites, traditional MET masts may not be feasible due to water depth. Alternative methods are needed to measure wind speed at multiple heights to determine wind shear profiles, wind speed, and atmospheric conditions in which wind turbines would operate. All offshore projects, particularly wind farms, will require this site-specific information. Collecting this data will require remote sensing equipment such as SODAR, LIDAR or coastal RADAR based systems, the development of new measuring methods and software programs, and stable buoy systems. Existing remote sensing methods have not yet been fully proven in on-shore or offshore applications to the satisfaction of all stakeholders, including financial institutions and utilities. Applicants are encouraged to team with commercial offshore energy project developers and/or commercial resource assessment firms to ensure that industry needs and priorities are fully considered in development of hardware and software product specifications, validation methods, and commercialization plans. Grant applications must: (1) demonstrate and validate new instrumentation concepts or improve existing technology to meet industry requirements for resource characterization; and (2) demonstrate the economic viability of the technology.

Contact: Chris Hart, 202-287-6676, chris.hart@ee.doe.gov

7e. Offshore Grid Infrastructure Hardware Development

Offshore wind and marine hydrokinetic projects require a subsea intra-array electrical grid and substations, plus connection to the utility grid via offshore transmission cables. Grant applications are sought for specification and design of innovative marine electrical hardware, cables and installation techniques optimized for the conditions and operating requirements of U.S. offshore wind or marine hydrokinetic farms. The goal of this activity is to encourage innovations that will lower balance-of-station capital expenditures, reduce transmission costs and operating faults, and facilitate practical solutions to bringing offshore wind or marine hydrokinetic power onto the land-based grid in large quantities. Applicants are encouraged to team with commercial offshore energy project developers and/or offshore electrical construction firms to ensure that industry needs and priorities are fully considered in development of hardware specifications, validation methods, and commercialization plans. Grant applications must: (1) demonstrate that the new design would address barriers to large-scale offshore marine grids; and (2) demonstrate the economic viability of the technology.

Contact: Chris Hart, 202-287-6676, chris.hart@ee.doe.gov

7f. Offshore Mooring and Anchoring Technology

New technology will be needed to address low-cost, easily deployable mooring systems for floating offshore wind and marine hydrokinetic systems. Floating platforms, mooring line systems, and anchor installation and deployment are all significant cost drivers. A new generation of drag embedment-type anchors or vertical-load anchors or other novel concepts could lower installation and deployment costs. Easily deployable anchor systems for all platform types that can be manufactured from low-cost materials and can be incorporated into simple float-out installation systems would help to lower the cost of installation for offshore energy platforms. Grant applications must: (1) demonstrate that the proposed technology would allow for easily deployable, versatile, robust mooring systems for offshore energy platforms; and (2) demonstrate the economic viability of the technology.

Contact: Chris Hart, 202-287-6676, chris.hart@ee.doe.gov

7g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Mark Higgins, 202-287-5213, mark.higgins@ee.doe.gov

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2. Ackermann, T., Negra, N.B, Todorovic, J., and Lazaridis, L., "Evaluation of Electrical Transmission Concepts for Large Offshore Windfarms," *Offshore Wind Proceedings*, October 2005.

Subtopic f:

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2. Liu, G., "Technology of SEPLA Anchors," Presentation at DOE Deep Water Wind Workshop, October 27, 2004.

8. ADVANCED TECHNOLOGY APPLICATIONS FOR BUILDINGS

DOE conducts research to improve the performance of buildings through systems integration and component R&D. Systems integration research and development activities analyze building components and systems and integrate them so that the overall building performance is greater than the sum of its parts, often using the components developed by BT. In turn, research and development of individual building components (such as envelope and equipment/appliances) provides the technical basis for significant contributions to achieving improved energy performance in buildings. This solicitation seeks innovative approaches in three component areas: cold climate heat pumps, buildings envelope materials, and two aspects of solid state lighting.

8a. High-Performance, Cold-Climate Heat Pumps for Residential and Commercial Buildings

The Department of Energy is seeking the development of high-performance, cold-climate heat pumps for (a) residential buildings and (b) commercial buildings. Discussion. While heat-pump technology can provide high-efficiency climate control, there are currently no strong candidates for air source heat pump system designs that maintain both capacity and COP in cold climates. If these systems were developed, they could have a significant energy-savings impact in cold regions, particularly where natural gas is not available. Possible system designs could include multi-stage units, alternative refrigerants, or other innovative approaches that maintain performance and cost competitiveness. Because the building stock increases by only a few percent annually, successful design concepts must be applicable to both new construction and retrofits of existing buildings. Performance targets are shown:

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Cold-Climate Heat Pump Performance Targets		
Ambient Temperature (°F)	Minimum COP	Maximum % capacity degradation from nominal
47 (nominal rating point)	4	0
17	3.5	10
-13	3	25

All grant applications submitted in response to this topic should include the following: (1) a detailed evaluation showing how the proposed concept advances the state-of-the-art (e.g., in terms of energy efficiency, reduced lifecycle costs, reliability, market share, etc.) and addresses a large potential market; (2) an outline of the proposed technology development process, pathway to commercialization, and potential public benefits that would accrue; and (3) a discussion of the ease of implementation of the new technology and its potential for high reliability. Phase I proposals should include (1) a preliminary design, (2) a characterization of laboratory-scale devices using the best measurements available, including a description of the measurement methods, and (3) a road map showing major milestones that would lead to a system that would be built and tested in Phase II. In Phase II, devices suitable for near-commercial applications must be built and tested, and issues associated with manufacturing the units in large volumes at a competitive price must be addressed.

Contact: Tony Bouza, 202-586-4563, Antonio.bouza@ee.doe.gov

8b. Advanced Materials for Building Envelope Applications

The Department of Energy is seeking the development of advanced materials for building envelope systems. These include materials for improved and variable (a) emissivities, and (b) reflectances.

a) While low-emissivity (low-e) surfaces have played a major role in improving window glazing and radiant barrier attic roof products, further development is needed. The best available emissivity for glass surfaces exposed to the environment is no lower than 0.15 (sealed insulated glass units can be as low as 0.02); spray-applied coatings generally result in emissivities no lower than 0.25. Development is needed on reducing these emissivity values, for an increased pallet of colors. Development is also needed on low-cost, variable-emissivity materials, for applications in areas with large diurnal or seasonal variations.
b) Development is needed on materials for variable solar reflectivity of roofing surfaces to allow for high solar reflectance in warm and hot conditions, but to adapt to a passive solar collection when heating gains are desirable. This area focuses on reflectivity of roofing surfaces only.

Because the building stock increases by only a few percent annually, successful design concepts must be applicable to both new construction and retrofits of existing buildings.

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All grant applications submitted in response to this topic should include the following: (1) a detailed evaluation showing how the proposed concept advances the state-of-the-art (e.g., in terms of energy efficiency, reduced lifecycle costs, reliability/durability, market share, etc.) and addresses a large potential market; (2) an outline of the proposed technology development process, pathway to commercialization, and potential public benefits that would accrue; and (3) a discussion of the ease of implementation of the new technology and its potential for high reliability/durability. Phase I proposals should include (1) a preliminary concept, (2) a characterization of laboratory-scale materials using the best measurements available, including a description of the measurement methods, and (3) a road map showing major milestones that would lead to the integration of the material into building envelope system prototypes that would be built and tested in Phase II. In Phase II, system-level prototypes suitable for near-commercial applications must be built and tested, and issues associated with manufacturing the units in large volumes at a competitive price must be addressed.

Contact: Marc LaFrance, 202-586-9142, marc.lafrance@ee.doe.gov

8c. Solid State Lighting: Inorganic Light Emitting Diodes (LEDs) - Substrates and Semiconductors for Inorganic Light Emitting Diodes (LEDs)

Inorganic Light Emitting Diodes (LEDs) have rapidly evolved during the past 20 years as viable components for energy efficient lighting in a variety of general illumination applications. However, despite their pervasive presence in the marketplace, a number of technical challenges continue to inhibit their expansion and market penetration into more mainstream lighting applications that represent large percentages of the primary energy consumed by electric lighting in US buildings and are of particular interest to the DOE. Improved substrates and semiconductors for light sources are sought to address these challenges.. Research is sought to develop alternative low cost, high quality substrates for LEDs that enable the growth of higher quality epitaxial layer structures. Candidate substrates shall be amenable to high efficiency manufacturing at low cost. Successful substrate approaches shall successfully demonstrate improvements in LED performance over state-of-the-art, under the metrics of reduced droop, improved thermal performance, or green external quantum efficiencies (EQE). Preference may be given to approaches that meet the above requirements while demonstrating feasibility for cost reduction of the LED through lower substrate cost, reduced fabrication costs, or improved yield. (MYPP subtask B1.1) Research is also sought for the development and deployment of efficient LED emitters with an emphasis on the production of white light with improved droop and thermal sensitivity parameters. Successful semiconductor material approaches shall demonstrate improved LED wall plug efficiencies at optimal wavelengths across the visible spectrum. (MYPP subtask B1.2)

As described fully in the DOE SSL Multi-Year Program Plan (MYPP) available for download at http://www1.eere.energy.gov/buildings/ssl/, a number of high priority research areas have been identified and are included here as an area of interest under this subtopic. Applicants must specifically respond to the area of interest and must include sufficient technical, price and performance information to permit a full review. ***Technical information included in proposals should include specific reference to one or more of the appropriate areas of the MYPP.*** Projections of price or cost advantage due to manufacturing improvements, materials use or design simplification for example should provide references to current practices and pricing to enable informed comparison to present technologies. All performance claims must be fully justified with either theoretical predictions or experimental data. Failure to provide adequate technical information will be sufficient reason to immediately reject proposals as non-responsive.

Contact: Jim Brodrick, 202-586-1856, james.brodrick@ee.doe.gov

8d. Solid State Lighting: Development of Low-Cost Electrodes for Organic Light Emitting Diodes (OLEDs)

Advancements in Organic Light Emitting Diodes (OLEDs) have evolved with remarkable progress since the initial introduction of white phosphorescent designs almost 20 years ago. Like many other electronic organic materials systems that are popular today, a number of technical hurdles remain and are the subject of this subtopic. Improvement is sought for electrode structures to advance OLED technology. Applicants responding to this subtopic are encouraged to propose solutions that advance the technology, price and performance goals without compromising other attributes such as manufacturing ease or compatibility with existing manufacturing lines. Research is sought for the development of low cost, low voltage, transparent and stable electrode structures for efficient and uniform current injection for OLEDs. Successful approaches shall be compatible with high efficiency organic materials and be suitable for large-scale manufacturing. Attention shall be given to limiting surface roughness to prevent shorting. Acceptable design may include a conducting grid, segmented structures, light extraction enhancements, and/or charge injection enhancement layers. (MYPP subtask D2.2)

As described fully in the DOE SSL Multi-Year Program Plan (MYPP) available for download at http://www1.eere.energy.gov/buildings/ssl/, a number of high priority research areas have been identified and are included here as an area of interest under this subtopic. Applicants must specifically respond to the area of interest and must include sufficient technical, price and performance information to permit a full review. ***Technical information included in proposals should include specific reference to one or more of the appropriate areas of the MYPP.*** Projections of price or cost advantage due to manufacturing improvements, materials use or design simplification for example should provide references to current practices and pricing to enable informed comparison to present technologies. All performance claims must be fully justified with either theoretical predictions or experimental data. Failure to provide adequate technical information will be sufficient reason to immediately reject proposals as non-responsive.

Contact: Jim Brodrick, 202-586-1856, james.brodrick@ee.doe.gov

8e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Jim Brodrick, 202-586-1856, james.brodrick@ee.doe.gov

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9. ENERGY EFFICIENT MEMBRANES FOR INDUSTRIAL APPLICATIONS

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

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

Despite the successes and advancements, many challenges must be overcome before membrane technology becomes more widely adapted. Technical barriers include fouling, instability, low flux, low separation factors, and poor durability. Advancements are needed that will lead to new generations of organic, inorganic, and ceramic membranes. These membranes require greater thermal and chemical stability, greater reliability, improved fouling and corrosion resistance, and higher selectivity. The objective is better performance in existing industrial applications, as well as opportunities for new applications. To advance the use of membrane separations, research is needed to develop new, more effective membrane materials and innovative ways to incorporate membranes in industrial processes. Grant applications must address the potential public benefits that the proposed technology would provide, both from reduced energy consumption and from the reduction in one or more of the following: materials consumption, water consumption, and toxic and pollutants dispersion. Grant applications should also include a plan for introducing the new technology into the manufacturing sector, in order to access capabilities for widespread technology dissemination.

Grant applications are sought only in the following subtopics:

9a. Membrane Materials with Improved Properties

Grant applications are sought to develop lower cost inorganic, organic, composite, and ceramic membrane materials in order to improve one or more of the following properties: (1) increased surface area per unit volume, (2) higher temperature operation (e.g., by using ceramic or metal membrane materials), and (3) suitability for separating hydrophilic compounds in dilute aqueous streams. Particular membrane materials of interest include nano-composites, mixed organic/inorganic composites, and chemically inert materials. Particular processes/systems of interest include membranes for the separation of biobased products, membranes for hydrogen

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separation and purification, membranes for CO_2 capture, and membranes for industrial applications.

For industrial applications, high temperature separations of hydrocarbons and other mixtures are of particular interest. For example, low molecular weight hydrocarbons are separated from natural gas by condensing them as a liquid, and the liquid is distilled to fractionate it, or the liquid is hydrocracked to olefins. However, chilling the natural gas in order to recover the condensable portion and then reheating it is inefficient, because the energy used to chill it cannot be recovered. Membranes, either as standalone systems or hybridized with other separation technologies, may provide an energy efficient means of separating mixtures at the high temperatures at which these industrial processes are carried out.

For all membrane processes/systems, grant applications must be targeted toward the development of specific membrane materials for carefully defined commercial applications; efforts focused on generalized membrane material research are not of interest and will be declined. In order to assure the rapid commercialization of the technology, especially for use by U.S. manufacturers, applicants are strongly encouraged to engage in partnerships, so that the costs of the technology development and commercialization can be shared among manufacturers, suppliers, and end users.

Contact: Charles Russomanno, 202-586-7543, Charles.Russomanno@hq.doe.gov

9b. Membrane Technologies for the Petroleum and Petrochemical Process Industries
This subtopic solicits innovation research for the development of membrane technology to reduce distillation energy in petroleum refinery and petrochemical separation processes. Large-scale industrial distillation accounts for about one-sixth of the annual energy consumed by the petroleum and petrochemical process industries, making it the single most energy intensive process of all US industrial processing. Since the energy savings potential for reducing distillation is so large considerable R&D for membrane technologies with potential applications in the petrochemical process industries has already been invested; nevertheless, membrane technologies have so far contributed marginally to distillation energy reduction in commercial application. Cost considerations have been the barrier to industrial hydrocarbon separations assisted by membranes. Grant applications for innovation research in membrane technology development for petroleum and natural gas liquid hydrocarbon separations are solicited that will reduce distillation process energy in any of the hydrocarbon separation process steps. The application must address aliphatic or aromatic hydrocarbon separations alone, and thus Phase 1 grant applications for innovation research in oxygenated or other chemical product membrane separations are not responsive to this subtopic solicitation. By far the most important aspect of this subtopic solicitation is the understanding of R&D that has already been invested in membrane technologies for hydrocarbon separations, and an understanding of the barriers to the development and commercialization of those membrane technologies. Thus thorough patent and literature searches are imperative to the preparation of responsive applications to the subtopic, and for this and for the promise of eventual commercialization of successful new technologies the partnerships of small technology business and US industrial companies are strongly encouraged.

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Contact: Charles Russomanno, 202-586-7543, Charles.Russomanno@hq.doe.gov

9c. Industrial Membrane Process Systems

Grant applications are sought to enhance the separation capabilities of membranes used in industrial process streams. Proposed research should be aimed at developing and commercializing innovative membrane systems, using new or currently existing membranes, that can be robust when integrated within real-world processes (e.g., inert gas removal, isomer separation, aromatic/non-aromatic separations, sulfur removal, CO_2 capture, and removal of trace metals). Grant applications should seek to address one or more of the following needs: (1) techniques for overcoming scale-up problems related to contaminants in industrial streams (fouling, oil misting, etc.), (2) manufacturing technologies that would reduce the cost of membrane modules, (3) anti-fouling and anti-flux schemes to improve the long-term operability of membrane systems, and (4) methods to regenerate membrane performance and lower membrane maintenance costs. Also of interest is the integration of membranes with other technologies (such as the integration of membranes with distillation systems, or with adsorption or extraction processes), in order to address specific process issues. For all grant applications, the overriding goal is to enhance U.S. industrial process efficiency to the maximum possible extent by increasing the separation process efficiency. Therefore, priority will be given to applications that carefully examine the efficiency of the proposed membrane technology within the targeted application. Grant applications should also include a process evaluation and an economic analysis along with the R&D effort. Lastly, technology partnerships involving U.S. manufacturers, suppliers, and end users are strongly encouraged.

Contact: Charles Russomanno, 202-586-7543, Charles.Russomanno@hq.doe.gov

9d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Charles Russomanno, 202-586-7543, Charles.Russomanno@hq.doe.gov

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10. TECHNOLOGIES RELATED TO ENERGY STORAGE FOR ELECTRIC DRIVE VEHICLES

Electric drive vehicles such as hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs) have been identified as one important way to address the

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challenges of the nation's dependence on imported oil and the need to reduce the emission of green house gases. Energy storage technology represents one of the critical barriers to the development and marketing of cost-competitive electric drive vehicles. The importance of energy storage technologies has been reflected in Recovery Act grants of $1.5B to help establish a domestic, vehicular battery industry. Although the energy storage requirements for these types of vehicles are somewhat different they must all be able to accept high power recharging pulses from regenerative braking. For all systems, the materials to be utilized should be plentiful, have low cost relative to the materials currently in vehicular batteries, be environmentally benign, and be easily recycled. Evaluation of the technology with regard to the above criteria should be performed in accordance with applicable test procedures or recommended practices as published by the Department of Energy (DOE), the U.S. Advanced Battery Consortium (USABC), or the FreedomCAR Partnership (see references that follow).

Grant applications are sought only in the following subtopics.

10a. Technology to Allow the Recovery and Reuse of "High-Value" Materials from Used Lithium-Ion Batteries

The introduction of electric drive vehicles into the marketplace will be accelerated by technologies that reduce the total life-cycle cost of their batteries. The recovery and processing of "high value" materials, such as electrode materials from used lithium-ion batteries, to yield materials that could be used in new batteries is one way to reduce total life-cycle costs. (For the purposes of this topic, an example of a "high value" material would be $LiCoO_2$, which could be used in a new cell; a "lower value" material would be a cobalt oxide that only could be used in a cell after undergoing a conventional synthesis process to produce battery grade $LiCoO_2$.) Such recovery and reuse could increase the residual value of a used battery and could provide materials for new batteries at a lower cost than if those materials were synthesized from normal starting materials. Therefore, grant applications are sought to develop and demonstrate technologies that would enable (1) the recovery of active materials from used lithium-ion batteries, and (2) the processing of these materials so that they might be used in new batteries. Grant applications must address the probable cost of the proposed technologies. If there is no cost advantage relative to the new materials, the grant application may be deemed non-responsive. Proposed technologies that enable the recovery of the maximum quantity and variety of material(s) from a cell are preferred. Technologies that focus on the recovery of elemental materials (e.g., cobalt metal) or that result in a significant portion of the incoming batteries being reduced to "slag" will be deemed non-responsive.

In Phase I, the recovery and processing technologies may be demonstrated on small quantities of similar cells, and the capability to reuse the materials shall be confirmed in cells of at least 200 mAh in size. Phase II must address the processing of large quantities of cells of multiple chemistries and demonstrate the performance of the recovered materials in cells of at least 2 Ah in capacity.

Contact: Brian Cunningham, 202-287-5686, brian.cunningham@ee.doe.gov

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10b. Technologies to Allow an Electrochemical Pouch Cell to Vent Quickly and Appropriately Under Abuse Conditions

Most electrochemical cells (including primary (non-rechargeable) storage cells, secondary (rechargeable) storage cells, and electrochemical capacitors) will build up internal pressure when subjected to electrical or physical abuse. In some cases this pressure can be so great that it will rupture the cell's container. An uncontrolled rupture is often accompanied by high temperatures, flying parts, and cell "runaway." Such an uncontrolled rupture would be very undesirable in an HEV or PHEV application. Work on sealed lithium primary cells has shown that a carefully designed vent that opens at an optimum pressure and has an optimum size can release the internal pressure in a way that will mitigate adverse behaviors and may even "quench" cell runaway. In lithium primary cells, an optimum vent mechanism is a function of the cell's design and its electrochemical components. Grant applications are sought to develop and evaluate technology that will allow pouch cells appropriate for use in a vehicular application to vent so as to avoid uncontrolled rupture with minimal undesirable side effects such as fire. It is expected that the proposed technology will be specific to a family of cells (such as lithium-ion batteries using specific components or a specific type of capacitor). The proposed technology may incorporate both modifications to the cell's internal components and to the cell's container (i.e. cell "additives" plus a carefully designed vent). Proposals should identify what cell system will be studied and explain why it would be appropriate for use in a PHEV.

In Phase I the proposed technology should be developed and evaluated in small cells. In Phase II the usefulness of the technology in vehicle-size cells should be confirmed under multiple forms of physical and electrical abuse. Phase II must also address any issues that must be resolved to allow the technology to be produced in a controlled, reproducible, low-cost manner. The proposed technologies should not have an adverse effect on cell properties such as electrical performance, calendar life, or cost.

Contact: Brian Cunningham, 202-287-5686, brian.cunningham@ee.doe.gov

10c. Development of Highly Efficient Bifunctional Oxygen Electrodes for Lithium-Air Batteries

Rechargeable lithium-air batteries offer great promise for transportation applications due to their high specific energy and energy density. A critical component is the bifunctional oxygen electrode. On charging, the electrode acts catalytically to evolve oxygen (the oxygen evolution reaction, OER) and on discharge acts to reduce oxygen (the oxygen reduction reaction, ORR). Proposals are sought to develop and demonstrate a bifunctional electrode suitable to couple with a lithium electrode in a proposed lithium air battery suitable for use in an electric drive vehicle. The membrane/electrolyte is not under development here, but a practical lithium-air battery architecture needs to be identified in the proposal.

Deliverables in Phase I should include characterized electrocatalyst, fabricated and tested electrodes (½ cell configuration), and electrochemical testing data on a coin or equivalent cell with lithium metal negative electrodes. A successful Phase I proposal should be able to cycle at least 5 times. The Phase I effort should also evaluate the limitations and failure modes of the technology and provide the basis for addressing these limitations during Phase II. Successful Phase II proposals will improve upon Phase I performance by increasing cycling to a couple hundred with rate capabilities typical in vehicle applications. Proposals must demonstrate the cell performance of the developed bifunctional air electrode through a low cost manufacturing route with cells greater or equal to 2 Ah in capacity.

Contact: Brian Cunningham, 202-287-5686, brian.cunningham@ee.doe.gov

10d. Development of Measurement Tools and Systems to Improve Manufacturing Processes for Lithium-Ion Cells

The cost of electric drive vehicle batteries is greatly influenced by the level of maturity of its manufacturing process. Generally, a robust process resulting in minimal manufacturing costs will focus on reducing material and processing costs, greater throughput, and higher yields. One way to achieve higher yields is through the use of advanced quality control systems which improve the quality of the products they are created to monitor.

The manufacture of lithium-ion cells involves many complex processes that require careful monitoring techniques and tools to ensure products adhere to strict product/process specifications. Average and point surface roughness, IR surface maps, XRF, pore size distribution, acoustic emission/absorption maps, and/or thermal emissivity maps are all possible modalities for real-time, continuous monitoring that would enable advanced quality control systems for automotive battery manufacturing. Proposals are sought to increase the yield rate on mass-produced batteries by providing for real-time, on-line quality control instruments. Proposals need to address how their technology improves upon state of the art automotive battery manufacturing monitoring techniques.

The Phase I effort should involve constructing and/or modifying existing instrumentation to perform the various measurements and performing proof-of-principle experiments. In Phase II, stand alone equipment is to be built and installed on partners' Li-ion battery assembly lines.

Contact: Brian Cunningham, 202-287-5686, brian.cunningham@ee.doe.gov

10e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Brian Cunningham, 202-287-5686, brian.cunningham@ee.doe.gov

REFERENCES

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

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

3. This site contains multiple references that summarize work supported by the Vehicle Technologies Program related to energy storage. Prior to 2002, there are separate publications for the Energy Storage Effort and for Advanced Technology Development. In more recent years, there is a combined report for Energy Storage. These reports include information about cell chemistries that have proven to be useful model systems for these applications along with discussions of issues related to abuse tolerance and cell life. Very useful presentations may also be found by following the links from Conferences Papers and Presentations 2010 Vehicle Technologies Annual Review. (URL: http://www.eere.energy.gov/vehiclesandfuels/resources/)

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

11. INSTRUMENTATION FOR ADVANCED CHEMICAL IMAGING

The Department of Energy seeks to advance chemical imaging technologies that facilitate fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels. The Department is particularly interested in forefront advances in imaging techniques that combine molecular-scale spatial resolution and ultrafast temporal resolution to explore energy flow, molecular dynamics, breakage, or formation of chemical bonds, or conformational changes in nanoscale systems.

11a. High Spatial Resolution Ultrafast Spectroscopy

Chemical information associated with molecular-scale processes is often available from optical spectroscopies involving interactions with electromagnetic radiation ranging from the infrared spectrum to x-rays. Ultrafast laser technologies can provide temporally resolved chemical information via optical spectroscopy or laser-assisted mass sampling techniques. These approaches provide time resolution ranging from the breakage or formation of chemical bonds to conformational changes in nanoscale systems but generally lack the simultaneous spatial resolution required to analyze individual molecules. Grant applications are sought that make significant advancements in spatial resolution towards the molecular scale for ultrafast spectroscopic imaging instrumentation available to the research scientist. The nature of the advancement may span a range of approaches including sub-diffraction limit illumination or detection, selective sampling, and coherent or holographic signal analysis.

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Contact: Larry A. Rahn, 301-903-2508, larry.rahn@science.doe.gov

11b. Time-Resolved Chemical Information From Hybrid Probe Microscopy's

Probe microscopy instruments (including AFM and STM) have been developed that offer spatial resolution of molecules and even chemical bonds. While probe-based measurements alone do not typically offer the desired chemical information on molecular timescales, methods that take advantage of electromagnetic interactions or sampling with probe tips have been demonstrated. Grant applications are sought that would make available to scientists new hybrid probe instrumentation with significant advancements in chemical and temporal resolution towards that required for molecular scale chemical interactions. The nature of the advancement may span a range of approaches and probe techniques, from tip-enhanced or plasmonic enhancement of electromagnetic spectroscopy's to probe-induced sample interactions that localize spectroscopic methods to the molecular scale.

Contact: Larry A. Rahn, 301-903-2508, larry.rahn@science.doe.gov

11c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Larry A. Rahn, 301-903-2508, larry.rahn@science.doe.gov

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12. TECHNOLOGY TO SUPPORT BES USER FACILITIES

The Office of Basic Energy Sciences (BES), within the DOE's Office of Science, is responsible for current and future user facilities including synchrotron radiation, free electron lasers, and the Spallation Neutron Source (SNS). This topic seeks the development of technology to support these user facilities.

Grant applications are sought in the following subtopics:

12a. Synchrotron Radiation Facilities

As synchrotron radiation has become a ubiquitous tool across a broad area of forefront science, the DOE supports collaborative research centers for synchrotron radiation science. Research is needed for advanced detectors and advanced radiation sources, including superconducting and short-period undulators. With advances in the brightness of synchrotron radiation sources, a wide gap has developed between the ability of these sources to deliver high photon fluxes and the ability of detectors to measure the resulting photon, electron, or ion signals. At the same time, advances in microelectronics engineering should make it possible to increase data rates by orders of magnitude, and to increase energy and spatial resolution. With the development of fourth-generation x-ray sources with femtosecond pulse durations, there will be a need for detectors with sub-picosecond time resolution. Therefore, grant applications are sought to develop new detectors for synchrotron radiation science across a broad range of applications. Areas of interest include: (1) area detectors for diffraction experiments; (2) area detectors for readout of electron and ion signals; (3) detectors capable of ultra-high temporal resolution; (4) high resolution and/or high frame rate imaging detectors; (5) detectors for high rate fluorescence spectroscopy; and (6) detectors for high energy fluorescence spectroscopy. Often, detector concepts or protoypes already exist in the community, and the primary hurdle is commercialization. Therefore, proposed approaches that emphasize engineering for commercialization are also of interest.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

12b. Beam Diagnostic Instrumentation for Free Electron Lasers and 3rd Generation Light Sources

Advanced electron-beam diagnostic instruments are needed to support the development of X-ray Free Electron Lasers (FEL), as well as the operation and upgrade of 3rd generation light sources. Grant applications are sought to develop monitors for beam position and electron bunch length. The beam position monitor should have nanometer resolution and associated electronics for both linac and storage ring applications. The electron beam bunch length monitor should perform non-destructive measurements, be capable of single-bunch resolution better than 100 fs, and possess a system design that is relevant for the bunch parameters of the future X-ray FEL and 3rd generation light sources.

Grant applications also are sought to develop diagnostic devices for the non-destructive measurement of electron beam emittance and for the energy spread within electron bunches. For FEL applications, measurements of electron bunch properties require resolution on the order of 10 μm, so that the so-called “slice” properties can be determined with sufficient accuracy. Both the beam emittance and the energy spread of the beam are critical parameters in FELs, and the measurement techniques must allow for rapid and noninvasive tuning, as well as for the implementation of feedback systems for systems optimization. Approaches of interest include optical techniques that employ transition radiation or synchrotron radiation. The diagnostics should be small (< 1 m length scale) and suitable for integration into an operational light source. Grant applications also are sought to develop diagnostics for the measurement of charge modulation within an electron bunch at optical wavelengths in the regime 50-1000 nm. Seeded FELs utilize an inverse FEL scheme to first introduce an energy modulation into an electron bunch; then a dispersive transport region converts the energy modulation into a charge density modulation along the electron bunch. The charge density is modulated with the same period as the laser, i.e., in the wavelength regime 50-1000 nm.

Grant applications also are sought to develop a diagnostic technique for the dynamic measurement of the transverse position of the centroid of an electron bunch, as a function of position along that bunch. The transverse wakefields in a linac may introduce the so-called

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"banana shape" beam as a result of the beam-breakup instability, in which deflecting wakefields introduce a transverse spatial offset in the electron distribution along a bunch. Proposed diagnostics must be able to measure this effect with spatial resolution on the order of 1 µm, and with temporal resolution (along the bunch) of 10-100 fs, in bunches of peak current 10-500 A. Finally, grant applications are sought to develop high resolution multi-function diagnostics. cavity beam position monitors (BPMs), which are well suited for LINAC applications as well as for advanced storage rings and energy recovery linacs (ERLs), represent one approach of interest. Such cavity BPM diagnostics should (1) have measurement capabilities that include sub-micron positioning, beam tilt, and charge; and (2) be physically small and low cost, in order to enable commercialization.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

12c. High Power Mercury Spallation Targets

Technology is needed to mitigate cavitation damage erosion (CDE) in short-pulse liquid-mercury spallation targets. CDE has the potential to limit the power capacity and lifetime of targets. Damage has been observed inside test target vessels irradiated with small numbers of intense proton beam pulses; also, this damage has been studied at length in out-of-beam experiments that mimic the driving mechanism of cavitation. The damage is caused by intense and abrupt pressure waves that are induced by the near-instantaneous heating of the mercury by the proton beam. Although certain surface hardening processes have shown promise in resisting damage, their potential to greatly enhance power capacity is believed to be limited. Therefore, grant applications are sought to develop:

Small gas bubbles to reduce beam-induced pressure. A population of small gas bubbles introduced in the mercury could absorb and attenuate the beam-induced pressure sufficiently to halt the driving mechanism for cavitation. The desired bubble size is approximately 10 µm in diameter and the required void fraction approaches 1%. Grant applications are sought to develop: (1) techniques for generating this population of bubbles in mercury; and (2) credible diagnostics to quantify the generated population.

Protective gas layers. Mercury, with its highly non-wetting characteristic and high surface tension is well suited to the formation and stabilization of large gas pockets. Therefore, one promising option for damage mitigation involves the creation of an interstitial gas layer between the liquid metal and the containment vessel wall.

Innovative gas/liquid flow concepts for utilizing gas layers to protect pressure-vessel surfaces from damage due to the cavitation of flowing mercury. Approaches of interest include: (1) the use of radiation-hard solid materials, such as metallic porous media or screens, as separate structures that are not part of the pressure boundary; (2) extensive surface modifications, such as grooves or cross-hatching to increase surface area; or (3) other geometries designed to trap gas permanently at the desired location. Because the most vulnerable pressure boundary surfaces in the SNS target are vertical, proposed solutions must address the problem of blanketing (protecting) vertical surfaces, where the hydrostatic gradient tends to force the gas to rise.

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Alternative and innovative concepts for damage mitigation, aside from small gas bubbles or protective gas walls. Grant applications must demonstrate an awareness of spallation target design and environmental requirements, with respect to high radiation and mercury compatibility.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

12d. Instrumentation for Ultrafast X-ray Science

The Department of Energy seeks to advance ultrafast science dealing with physical phenomena that occur in the range of one-trillionth of a second (one picosecond) to less than one-quadrillionth of a second (one femtosecond). The physical phenomena motivating this subtopic include the direct observation of the formation and breaking of chemical bonds, and structural rearrangements in both isolated molecules and the condensed phase. These phenomena are typically probed using extremely short pulses of laser light. Ultrafast technology also would be applicable in other fields, including atomic and molecular physics, chemistry and chemical biology, coherent control of chemical reactions, materials sciences, magnetic- and electric field phenomena, optics, and laser engineering.

Grant applications are sought to develop and improve laser-driven, table-top x-ray sources and critical component technologies suitable for ultrafast characterization of transient structures of energized molecules undergoing dissociation, isomerization, or intramolecular energy redistribution. The x-ray sources may be based on, for example, high-harmonic generation to create bursts of x-rays on subfemtosecond time scales, laser-driven Thomson scattering and betatron emission, and laser-driven K-shell emission. Approaches of interest include: (1) high-average-power ultrafast sources that achieve the state-of-the-art in short-pulse duration, phase stabilization and coherence, and high duty cycle; (2) driving lasers that operate at wavelengths longer than typical in current CPA titanium sapphire laser systems; and (3) characterization and control technologies capable of measuring and controlling the intensity, temporal, spectral, and phase characteristics of these ultrashort x-ray pulses.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

12e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

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13. RADIO FREQUENCY (RF) DEVICES AND COMPONENTS FOR ACCELERATOR FACILITIES

The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light sources, free electron lasers, and spallation neutron source user facilities. This topic seeks the development of radio frequency devices and components to support these user facilities.

Grant applications are sought in the following subtopics:

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13a. Klystrons and Inductive Output Tubes (IOTs)

Grant applications are sought to develop higher order mode (HOM) inductive output tube (IOT) continuous wave (CW) amplifiers at 200 kW CW (in the case where each cavity has its own amplifier). Such a device could provide lower operating voltage, smaller size, and lower operating cost than current klystrons, with approximately 15-20% higher efficiency. An IOT that could operate at ~70% efficiency (a level now approached by television IOTs depressed collectors) significant energy cost savings. An IOTs that is tunable over a reasonable range also would be desirable.

Grant applications also are sought to develop a pulsed inductive output tube (IOT) amplifier at 402.5 MHz, 140 kW, and 10% duty factor for a low-energy bunching application for high power H-/proton beams.

Finally, grant applications are sought to develop a 2.815GHz CW klystron (~100kW), preferably with two output windows, that would be suitable for a superconducting RF cavity.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13b. Higher Order Mode Damper Integrated into Beam Pipes

Grant applications are sought for the integration of ferrites into beam pipes adjacent to RF cavities, in order to damp parasitic higher order modes. Although such a technique has been developed at accelerator laboratories, it never has been industrialized.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13c. RF Cavity Input Couplers

Grant applications are sought to develop (1) a variable input coupler for both normal-conducting and superconducting RF cavities – approaches must demonstrate a significant increase in mechanical complexity compared with fixed coupler designs and provide for adjustments of the input coupler beta *in situ*, in order to optimize the RF system efficiency; (2) a high power fundamental power coupler for energy recovery linac (ERL) injector cavities with the following specifications: 1408 MHz operating frequency, average RF power up to 200 kW in traveling waver (TW) mode, nominal external Q of 5 x 10^4, and factor-of-10 variable coupling with minimum transverse kick to the beam; (3) an adjustable 20-way 40 kW CW power combiner operating at 352 MHz; and (4) a coaxial H-loop normal-conducting RF cavity input coupler for 352 MHz, which is capable of operation at 500kW forward power under infinite VSWR conditions and is compatible with a half-height WR2300 waveguide transition.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13d. RF Power Devices and Accessories

Grant applications are sought to develop (1) higher power Insulated Gate Bipolar Transistors (IOTs) with more than 6000Volts and more than 2000Amps, which are required for the development of high power modulators and power supplies; (2) a very high power (100-400 kW) 350-500 MHz solid state power amplifier to replace klystron amplifiers in synchrotron light sources; (3) a compact, water-cooled broadband 50-ohm RF load that can operate at 200kW CW input power and is resistant to the corrosive effects of the high-purity, de-ionized water that is used as a coolant; (4) new dielectric materials for vacuum-barrier RF windows for high-power applications, in order to significantly improve the power handling capability and mechanical strength (compared to existing materials), and demonstrate a low secondary electron emission coefficient; (5) a compact, high-power stripline-input broadband R termination, which is capable of 1kW CW input power and could be used for board-mounted components such as circulators and splitters/combiners; and (6) 4-way resonant cavity RF combiners of IOT power sources (the output of several IOTs must be combined to overcome their low power capability) to drive accelerating structures for high energy and high intensity accelerators that require several hundreds of kW.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13e. Modulators for High Level Radio Frequency (RF) Accelerator Systems
Grant applications are sought to develop a high-level amplitude and phase modulator (in either waveguide or coaxial topology) that can demonstrate modulation ability out to 20 kHz. Significant cost savings could be achieved if one klystron were used to drive multiple accelerating cavities, while retaining phase and amplitude control at the individual cavity level. Grant applications also are sought to develop (1) a 1KHz. 300 kV, 300A solid-state modulator for production of picosecond X-ray pulses using RF deflecting cavities; (2) a robust, high-average-power (200kW) 1 kHz modulator system that operates at approximately 300 kV and 300 A, with an ultimate rep rate at 1kHz or higher; (3) a robust, high-average-power (1.4 MW or greater) 60 Hz pulse modulator system that operates with a duty factor of 10 percent at various voltage and current ratings (for example, 140 kV at 90 A, 85 kV at 165 A); and (4) a solid state modulator for 40kV, 300A, 1 micosecond pulses at 60 Hz.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13f. Devices for the Manipulation of Electron Beams
Grant applications also are sought to develop devices for the manipulation of electron beams in storage rings and linear accelerators. Such devices are used to facilitate deflection of the beam onto a predicted trajectory or to generate a time-space correlation in the beam. Devices of interest include:

(1) Electromagnetic RF cavities operating in a dipole mode, which could introduce a transverse kick to an electron bunch as a whole or provide a “head-tail” displacement within the bunch. Such cavities would need to provide deflecting kick voltages up 10 MV, with phase error < 0.01° and amplitude error $< 10^{-4}$, with parasitic modes damped to Q-values < 1000 and with minimal short-range wake fields.

(2) Pulsed power supplies that can be used with stripline kickers to provide deflecting fields. Such power supplies should have a repetition rate up to 100 kHz, a voltage pulse 10-15kV, a 10 ns pulse duration, and pulse-to-pulse stability better than 10^{-3}.

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Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

13g. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

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2. ICFA Beam Dynamics Mini-Workshop on Deflecting/Crabbing Cavity Applications in Accelerators http://www.cockcroft.ac.uk/events/cavity/programme.htm

3. ICFA Beam Dynamics Mini-Workshop on Deflecting/Crabbing Cavity Applications in Accelerators, http://www.sinap.ac.cn/ICFA2008/Programs.htm

14. ADVANCED SOURCES FOR ACCELERATOR FACILITIES

The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light sources, free electron laser, and spallation neutron source user facilities. This topic seeks the development of technology to support the particle and radiation sources needed for these user facilities.

Grant applications are sought in the following subtopics:

14a. Electron Gun Technology

Grant applications are sought to develop novel electron gun features including:

(1) Robust cathode materials suitable for production of low emittance electron bunches at a high repetition rate, using laser excitation. The intrinsic normalized emittance of the electron beam must be of order 10^{-7} m-rad, in bunches of order 100 pC charge, duration of approximately 10 ps, and with quantum efficiency of 10^{-2} or greater. Materials should be robust to environmental conditions, have small dark current under applied electric fields of order 10-100 MVm^{-1}, and have long lifetime.

(2) Accelerating structures supporting electric fields of 10-100 MVm^{-1} at a cathode surface, allowing laser excitation of the cathode material and rapid acceleration of the emitted electrons, with minimal emittance growth and an electron bunch repetition rate of 1 MHz or greater. Combined with suitable cathode materials and a photocathode laser, the system should be capable of producing low emittance (less than 1 mm-mrad normalized) electron bunches at a minimum 1 MHz repetition rate, with up to 1 nC charge per bunch.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

14b. High Brightness Sources of Negative Hydrogen Ions

Grant applications are sought to develop high-current, high brightness sources of negative hydrogen ions. The goal is the production of ~70 mA of H- with a normalized emittance of 0.2 π mm·mrad, or about 100 mA with a normalized emittance of 0.35 π mm·mrad. These currents and emittances have to be achieved for 1.2 ms long pulses at 60 Hz. The current should remain constant within ~5%. The lifetime, as well as the mean-time-between-failure, should exceed several months. Of special interest are highly efficient ionization technologies that can produce such beams with moderate power levels (< 40 kW peak power) and use a minimum of cesium (<<1mg/day).

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Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

14c. Undulator Radiation Sources

Advanced undulator radiation sources are required for current and future light sources. Grant applications are sought for the development of:

1. Superconducting undulators (SCUs) that can generate tunable, monochromatic x-ray beams in the 2-30 keV photon energy range of medium-energy (2-3 GeV) synchrotrons. These requirements demand that the undulators have a short period (around 1.5 cm) and high peak magnetic fields (around 1.6 tesla). The permanent-magnets commonly used in undulators do not produce sufficiently high magnetic fields to fully cover the desired photon energy range without gaps in the spectrum. Development efforts are underway at several national laboratories and in industry to develop SCUs that promise to overcome these deficiencies. However, current designs suffer from an inability to operate without quenching in the presence of the heat induced by the stored electron beam current and by synchrotron radiation encountered in modern synchrotron light sources. This heat load can be up to 10 watts per meter of undulator length. Novel ideas for SCU design, construction, and thermal management are needed to meet these challenging requirements.

2. Superconducting undulators with time varying fields. This technology is in its infancy and could offer interesting possibilities for insertion-device radiation sources

3. Cryogenically-Cooled Permanent Magnet Undulators (CPMUs). When permanent magnet materials are cooled to low temperatures, they exhibit a large coercivity (5-10%) for conventional materials, such as NdFeB or CoSm, and up to 20% for more exotic materials. To make use of this effect, undulators must be cooled to cryogenic temperatures, and, in the cooled down stage, magnetic measurements and adjustments of the permanent magnet must be performed. This requires a complex design.

4. High coercivity permanent magnet materials for CPMUs. To take full advantage of CPMUs, sintering and manufacturing procedures need to be developed for permanent magnet material like PrFeB, which exhibits large increases in coercivity at cryogenic temperatures.

5. New superconducting materials for undulator applications. Three types of materials promise a considerable enhancement of undulator performance:

High temperature superconducting materials such as YBCO, which operate at about 90K, would allow current densities up 100kA/mm^2. The challenge here is to optimize the conductor design to maximize the current density and the transport current, leading to the development of coil manufacturing techniques based on such materials (as the next step).

Thin film high temperature superconducting materials such as MgB_2, which are operated at ~39K, may become a good material for undulator magnets, depending upon the choice of substrate material, which will determine the mechanical properties of the superconductor. The challenge here is the production of thin films and the choice of optimum substrate materials.

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APC (artificially enhanced pinning center) NbTi superconductor, which would allow super-high current densities that exceed the Jc of conventional NbTi superconductor by a large factor (14 kA/mm^2 at 2 T). In particular, the high current density might offer an advantage for the design of magnet coils for undulator magnets.

6. Undulators with period < 1 cm. The resonant condition requires undulator radiation at short wavelength (approximately 1 nm), with low energy electron beams (of 1-2 GeV), and with a shorter period than generally available from existing synchrotron radiation sources. The undulators should be designed with K-value ~1, impedance shielding of pole faces, and a gap that is greater than 2.25 mm.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

14d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

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15. ANCILLARY TECHNOLOGIES FOR ACCELERATOR FACILITIES

The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light sources, free electron laser, and spallation neutron source user facilities. This topic seeks the development of computational, control, and superconducting technologies to support these user facilities.

Grant applications are sought in the following subtopics:

15a. Accelerator Modeling and Control

Grant applications are sought to develop new or improved computational tools for the design, study, or operation of charged particle beams. Of particular interest is the development of a front-end design for user-friendly interfaces. The modeling challenges addressed must be relevant to present and future BES accelerator facilities. These challenges include, but are not limited to, beam halo generation and control; generation and synchronization of sub-ps x-ray pulses; wakefield computation; multiple and single bunch collective instabilities; electron cloud generation and effects, especially in high intensity proton rings; and high-intensity operation (beam losses, thermal effects, etc.).

Grant applications also are sought to investigate and develop enhancements to the suite of tools in the Experimental Physics and Industrial Control System (EPICS), in order to better support existing facilities and meet the requirements of future machines. Areas of interest include, but are not limited to, high-availability alternative-communication protocols; enhanced functionality within the Input-Output Controller; highly integrated development environments; and ensuring scalability to very large installations (such as the International Linear Collider). Grant applications should address how the results will guide long-term EPICS development.
As the time scale of interest in modern accelerators is reduced, the required computational resources are becoming prohibitive for currently-available low-order electromagnetic codes; for example, the estimated memory requirement for modeling a typical accelerator structure interacting with a 1-ps bunch is 1 TB. Such an extreme computation is intractable for most accelerator laboratories. Therefore, in order to break the computational bottleneck, grant

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applications are sought to develop computational electromagnetic codes with high-order accuracy.

Finally, grant applications are sought to develop large-scale timing and synchronization systems for next generation light sources, with timing stability requirements extending from ~100 femtosecons to 1 femtosecond or less. For example, these requirements include the need to enable the synchronization of multiple radio frequency components and laser systems, over distances of the scale of kilometers, in advanced accelerators and free electron lasers. This precision in timing must be maintained over periods of time on the order of 24 hours.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

15b. Superconducting Technology for Accelerators

Superconducting HOM-damped (higher-order-mode-damped) RF systems are needed for present and future storage ring and linac applications. Grant applications are sought to develop:

1. A high gradient (15-50 MVm^{-1}) 750 MHz superconducting cavity for linac-driven synchrotron radiation sources. The cavity should operate in CW mode with high efficiency of wall-plug-to-beam power conversion. Systems should be capable of supporting a beam current up to 500 mA, with parasitic mode Q-values below 1000, and minimal short-range wakefields.

2. A 1500 MHz passive superconducting Landau cavity for storage-ring bunch lengthening.

3. A superconducting RF power coupler capable of handling 500 kW CW RF power.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

15c. Cooling of Superconducting Systems

A fundamental conceptual issue has arisen concerning the cooling of superconducting linacs during high-power pulsed operation. At fast pulse (1 ms), high-average forward-power levels (~ 75 kW) and excessive thermal radiation loads from the fundamental couplers result in high couple surface temperatures, which reduce cavity stability and operating accelerating gradients. Therefore, grant applications are sought to develop innovative cooling concepts for fundamental power couplers, which do not impact the performance of the associated superconducting cavities. In addition, with the successful implementation of superconducting radiofrequency accelerating structures at facilities in all regions of the world, additional emphasis is being placed on reducing superconducting radiofrequency (SRF) cryomodule costs and improving manufacturing quality. Therefore, grant applications are sought for innovative concepts and design approaches to the manufacture of cryomodule assemblies containing multiple-processed SRF cavities. Approaches of interest include new cavity cooling and support systems, reliable cavity tuners and tuner components, and less expensive fundamental couple assemblies.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

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15d. Advanced Laser Systems for Accelerator Applications

Advanced laser systems are needed for photoinjectors, for Free Electron Laser Seeding, for current-enhanced self-amplified spontaneous emission (ESASE), for laser-ion stripping of hydrogen beams, and for laser wire beam profile measurements in proton particle accelerators. Grant applications are sought for the development of:

1. High power laser oscillator systems for high repetition rate (1-100 MHz) electron guns that can deliver pulses of 10-100 μJ energy in the 1 μm wavelength range, with pulses capable of being expanded to10-50 ps duration.

2. Laser pulse shaping systems that can modify the laser pulse in 3D, in order to minimize emittance growth due to space charge effect in a photoinjector. Approaches of interest include pulse stacking, laser phase modulation, and others. In general, the pulse should have a homogeneous intensity distribution (10% modulation) confined in a sharp boundary in three dimensions, with either a cylindrical or ellipsoidal geometry.

3. A mid-IR, carrier envelope phase (CEP) stabilized laser with tens of mJs of energy and a few carrier cycles within a Full-Width at Half-Max (FWHM) of 10-50 fs.

4. A mid-IR (2.0 micron) laser for E-SASE, with a pulse under 100 fs, possibly CEP-stabilized in the energy range of a few mJ.

5. Tunable lasers to be used as seeds for free electron lasers (FELs). The central wavelength should be within the wavelength range, 10-50 nm, and the laser should be continuously tunable within a band that is at least 20% of that wavelength range. Pulse duration should be adjustable and on order of 100 fs. Peak power within the pulse should be on order of 100 kW. Optical pulses should be reproducible on a shot-to-shot basis, with good temporal coherence within the pulse, good beam quality (M^2<1.3), and a repetition rate of 100 kHz or greater.

6. Lasers for laser-ion stripping of hydrogen beams. The lasers should have high repetition rate (~400 MHz), high peak power (~1MW), and picosecond 355 nm pulses to match the in-beam structure of the linac for Spallation Neutron Source (micropulses that are 50 ps long, separated by 2.5 ns, gated into minipulses of 650 ns that repeat at 1.058 MHz, and are bunched into 1 ms macropulses).

7. A laser power-recycling cavity at 355 nm to reduce average laser power requirements for ion stripping. Important design criteria include compactness, a length to match bunch repetition rate, stabilization to a small fraction of a wavelength, protection of mirrors from electron and gamma radiation, and an in-vacuum configuration.

8. Lasers for laser-wire-beam profile measurements with the following specifications:

- pulse energy of 100 mJ at 1064 nm;
- repetition rates of 30 or 60 Hz with external trigger;
- compact laser head with dimensions of approximately 6’x3”x3”;

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- no requirement for chilled water;
- a power supply remotely controllable through Ethernet cables; and
- radiation resistance for doses greater than 10^6 rads.

Based on previous experiments, the key components of a radiation-resistant laser system are the YAG crystal, the fold prism, a cube polarized in the laser head, and IC chips in the laser controller unit.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

15e. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Eliane Lessner, 301-903-9365, Eliane.Lessner@science.doe.gov

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16. INSTRUMENTATION FOR ELECTRON MICROSCOPY AND SCANNING PROBE MICROSCOPY

The Department of Energy supports research and facilities in electron and scanning probe microscopy for the characterization of materials. Innovative instrumentation developments offer the promise of radically improving these capabilities, thereby stimulating new innovations in materials science. Grant applications must address improvement in electron beam or scanning probe instrumentation capabilities beyond the present state-of-the-art.

Grant applications are sought in the following subtopics:

16a. Electron Microscopy and Microcharacterization

Electron microscopy and microcharacterization capabilities are important in the materials and biological sciences and are used in numerous research projects funded by the Department. Major advances are being sought for capability to characterize and understand materials, especially nanoscale particles, in their natural environment at high resolutions typical of electron microscopy and with good temporal resolution. To support this research, grant applications are sought to develop stages and holders that provide a suitable environment and also incorporate means to measure material behavior at the same time; electron sources and detectors that will provide more signal and better temporal resolution; and systems that automate simultaneous data collection, analysis, quantification, and feedback:

Stages and holders that provide new capabilities for *in situ* transmission electron microscopy experiments in liquid and/or gaseous environments. Approaches of interest should provide a capability to reach 80 Torr or higher during operation, and apply or measure at least two separate signals, such as current and voltage, at the same time. Proposed solutions must also be compatible with analytical energy dispersive spectroscopy.

New electron sources that can operate from pulsed modes to femtosecond frequencies. Of particular interest are laser-assisted field emission guns for application to pulsed mode operation in Transmission Electron Microscopy (TEM) mode.

Ultra-high efficiency spectrometers for analytical energy dispersive spectroscopy and/or electron energy loss spectroscopy. Approaches of interest should include efficient detector materials and improved geometry for maximum signal collection. Proposed solutions should also provide at least one additional integrated electron detector to allow parallel image and spectroscopic data acquisition without reorienting a sample. Proposed detectors must be robust and not susceptible to electron beam damage.

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Systems for automated data collection, processing, and quantification. Approaches of interest should include (1) hardware and platform-independent software for data collection and visualization, (2) automated measurement and mapping of crystallography, internal magnetic or electric field, or strain, and (3) multi-spectral analysis. Software and quantification routines for image reconstruction and for interpretation of interference patterns/holography are encouraged.

Contact: Jane Zhu, 301-903-3811, Jane.Zhu@science.doe.gov

16b. Scanning Probe Microscopy (SPM)

The enabling feature of nanoscience, as recognized in workshop reports sponsored by National Nanotechnology Initiative and by the Department of Energy, is the capability to image, manipulate, and control matter and energy on nanometer, molecular, and ultimately atomic scales. Scanning probe microscopy is vital to the advancement of nanoscience and nanotechnology, and is used in numerous materials research projects and facilities funded by the Department. Grant applications are sought to develop:

New generations of functional SPM probes, sample holders/cells (including electrochemical and photoelectrochemical cells), and controller/software support for ultrafast, environmental and functional detection. Areas of interest include: (1) insulated and shielded probes for high-resolution electrical imaging in conductive solutions; (2) probes integrated with electro-optical switches for ultrafast imaging; (3) heated probes combined with dynamic thermal measurements including thermomehcnical, temperature, and integrated with Raman and mass-spectrometry systems, and (4) probes integrated with electrical, thermal, and magnetic field sensors for probing dynamic electrical and magnetic phenomena in the 10 MHz - 100 GHz regime. Probes and probe/holder assemblies should be compatible with existing commercial hardware platforms, or bundled with adaptation kits. Complementary to this effort is the development of reliable hardware, software, and calibration methods for the vertical, lateral, and longitudinal spring constants of the levers, sensitivities, and frequency-dependent transfer functions of the probes. A new generation of optical and other cantilever detectors for beam-deflection-based force microscopies. Areas of interest include: (1) low-noise laser sources and detectors approaching the thermomechanical noise limit, (2) high bandwidth optical detectors operating in the 10-100 MHz regime, and (3) small-spot (sub-3 micron) laser sources for video-rate Atomic Force Microscopy (AFM) measurements. Piezoresistive and tuning-fork force detectors compatible with existing low-temperature high-magnetic field environments are also of interest.

Systems for next-generation controllers and stand-alone modules for data acquisition and analysis. Areas of interest include: (1) multiple-frequency and fast detection schemes for mapping energy dissipation, as well as mechanical and other functional properties; (2) active control of tip trajectory, grid, and spectral acquisition; and (3) interactive SPMs incorporating decision making process on the single-pixel level. Proposed systems should include provisions for rapid data collection (beyond the ~1kHz bandwidth of feedback/image acquisition of a standard SPM), processing, and quantification; and hardware and platform-independent software for data collection and visualization, including multispectral and multidimensional image analysis (i.e., for force volume imaging or other spectroscopic imaging techniques generating 3D or 4D data arrays). For rapid data acquisition systems, software and data processing algorithms for data interpretation are strongly encouraged.

Environmental SPM systems operating in the 10^{-8} Torr - 1 atm pressure range, supporting existing topographic, electrical, magnetic, mechanical, piezoelectric, and other imaging modes, for energy research. Particularly of interest are (a) variable pressure environmental cells that can be adapted to existing instrumental platforms, and (b) environmental cells compatible with aperture and apertureless optical and microwave imaging, as well as imaging modalities providing local chemical information.

Contact: Jane Zhu, 301-903-3811, Jane.Zhu@science.doe.gov

16c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Jane Zhu, 301-903-3811, Jane.Zhu@science.doe.gov

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17. INSTRUMENTATION FOR MATERIALS RESEARCH USING ULTRA-BRIGHT OR ULTRA-FAST X-RAY SOURCES

The Department of Energy supports X-ray scattering and spectroscopy facilities at synchrotron radiation and free electron laser (FEL) sources where users conduct state-of-the-art materials research. Their experiments are enabled by the convergence of a range of instrumentation technologies. This topic seeks to develop advanced instrumentation that will enhance materials research employing ultra-bright or ultra-fast x-ray sources. Grant applications should define the instrumentation need and outline the research that will enable innovation beyond the current state of the art. Applicants are strongly encouraged to demonstrate applicability and proper context through collaboration with a successful materials science researcher who utilizes ultra-bright or ultra-fast x-ray sources in their research program. To this end, the STTR program would be an appropriate vehicle for proposal submission. Alternatively, applicants are encouraged to demonstrate applicability by providing a letter of evaluation and support from a successful user. Priority will be given to those grant applications that include such collaborations or letters of support.

A successful user is defined as someone at a research institution who has recently performed synchrotron or FEL experiments and published results in peer reviewed archival journals. Such researchers are the early adopters of new instrumentation and are often involved in conceptualizing, fabricating, and testing new devices. A starting point for developing collaborations would be to examine the annual activity reports from synchrotron radiation or FEL facilities with links at: http://www.lightsources.org/cms/?pid=1000444

In all cases, the proposed instrumentation development must be motivated by at least one specific example of how a state of the art materials research project will be enabled. The proposal should delineate why a type of materials research is not currently possible and how the successful creation of the new instrumentation will enable access to new types or quanties of experimental data.

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Grant applications are sought in the following subtopics.

17a. X-ray Sources and Optics

X-ray scattering and spectroscopy experiments are often limited by the beam quality delivered to the research sample. Beam quality requirements depend on specific experiments but usually involve improvements in delivered x-ray flux, brightness, coherence, or focus size. Grant applications are sought to develop advanced instrumentation for creating, focusing, diffracting, or defining the X-ray beam that eventually illuminates the research sample. Areas of interest include source development of university lab scale or "table top" x-ray generators of ultra-fast (fs) pulses and advancements in beam manipulation devices such as mirrors, monochromator crystals, and focusing optics, in such a manner that improves the beam quality available for materials research. Grant applications should demonstrate an understanding of existing source capabilities in terms of beam quality delivered to a materials sample under investigation, and improve on some aspect that enhances the state of the art. Grant applications must demonstrate that proposed components and instruments will be able to handle the heating loads from intense x-ray beams, and meet the necessary stability requirements with respect to motion control and vibration isolation.

Contact: Lane Wilson, 301-903-5877, lane.wilson@science.doe.gov

17b. Control of Sample Environment

Experiments involving x-rays as a probe have the advantage of being able to penetrate a sample environment and retrieve information from samples that are maintained in realistic environmental conditions. However, the interaction of the x-rays with the environmental container and sample manipulation devices must be controlled to minimize absorption and background scattering. The position of the input and exit beam relative to each other and to the orientation of the sample often also must be carefully controlled. Grant applications are sought to develop technology for sample manipulation, in order to provide for the *in situ* control of environmental parameters. These parameters may include extreme temperatures and pressures, and chemical exposure. Sample manipulation systems of interest could include innovations in containers, motion stages, and windows, all compatible with the necessary data collection techniques of an envisioned materials research experiment.

Contact: Lane Wilson, 301-903-5877, lane.wilson@science.doe.gov

17c. Detectors

Scattering and spectroscopic data collection involves x-ray detectors that have advanced spatial, energy, and/or time resolution capabilities. The ability to complete a materials research experiment in a reasonable amount of time is often limited as much by the x-ray detection capability as by the quality of the x-ray source. Rapid coverage of the experimental phase space is desired, and multi-element detectors and detector arrays are often employed towards this end. As a result of improvements in x-ray fluxes, detectors often must be able to handle high count rates and large dynamic ranges. Grant applications are sought to advance the state of the art for x-ray detectors. Improvement in the quality and affordability of such detectors is an example of an appropriate area for proposed research. Because detector needs are defined by the needs of a

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materials experiment, grant applications must detail what new specific materials experiments will be enabled by the proposed improvement, if successfully realized.

Contact: Lane Wilson, 301-903-5877, lane.wilson@science.doe.gov

17d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Lane Wilson, 301-903-5877, lane.wilson@science.doe.gov

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18. INSTRUMENTATION AND TOOLS FOR MATERIALS RESEARCH USING NEUTRON SCATTERING

As a unique and increasingly utilized research tool, neutron scattering makes invaluable contributions to the physical, chemical, and biological sciences. The Department of Energy supports neutron scattering and spectroscopy facilities at neutron sources where users conduct state-of-the-art materials research. Their experiments are enabled by the convergence of a range of instrumentation technologies. The Department of Energy is committed to enhancing the operation and instrumentation of its present and future neutron science facilities (References 1-3) so that their full potential is realized.

This topic seeks to develop advanced instrumentation that will enhance materials research employing neutron scattering. Grant applications should define the instrumentation need and outline the research that will enable innovation beyond the current state-of-the-art. Applicants are strongly encouraged to demonstrate applicability and proper context through collaboration with a successful user of neutron sources. To this end, the STTR program would be an appropriate vehicle for proposal submission. Alternatively, applicants are encouraged to demonstrate applicability by providing a letter of support from a successful user. Priority will be given to those grant applications that include such collaborations or letters of support.

A successful user is defined as someone at a research institution who has recently performed neutron scattering experiments and published results in peer reviewed archival journals. Such researchers are the early adopters of new instrumentation and are often involved in conceptualizing, fabricating, and testing new devices. A starting point for developing collaborations would be to examine the annual activity reports from neutron scattering facilities with links at: http://www.ncnr.nist.gov/nsources.html and http://www.ncnr.nist.gov/.

Grant applications are sought in the following subtopics.

18a. Advanced Detectors
Develop advanced detectors with high efficiency and high resolution position sensitive neutron detectors for neutron diffraction and imaging. With the severe shortage of 3He innovative alternative detector technologies with similar or better performance are required for the current and future neutron scattering facilities.

Contact: Thiyaga P. Thiyagarajan, 301-903-9706, P.Thiyagarajan@science.doe.gov

18b. Advanced Optical Components
Develop novel or improved optical components for use in neutron scattering instruments (References 4-6). Such components include, neutron choppers, neutron guides, neutron lenses and focusing mirrors, neutron monochromators, neutron polarization devices including ^3He polarizing filters, radio-frequency flippers, superconducting coils, and Meissner shields. Grant applications also are sought for novel uses of such components in neutron scattering instruments.

Contact: Thiyaga P. Thiyagarajan, 301-903-9706, P.Thiyagarajan@science.doe.gov

18c. Advanced Sample Environment
Develop instrumentation and techniques for advanced sample environment (Reference 7, 8) for neutron scattering studies, with an emphasis on controlled chemical and gaseous environment. These environment should simulate conditions relevant to energy-related materials and should provide a novel means of achieving extreme sample conditions of temperature, pressure, electric and magnetic fields (or combinations thereof).

Contact: Thiyaga P. Thiyagarajan, 301-903-9706, P.Thiyagarajan@science.doe.gov

18d. Software Infrastructure
Development of user friendly software tools that enhance the utilization of the data produced by neutron and x-ray scattering and imaging instruments (References 2,3), thereby supporting the next generation of discovery science via data intensive, multi-technique experiments at multiple facilities. In particular, software is needed for the co-location of these data and to enable robust access by the experimental team, so that team members would have a user-friendly means of working with the data. Also of interest is advanced software tools for reduction, analysis, and simultaneous modeling of x-ray and neutron scattering data. The existing DOE ESnet

infrastructure (http://www.es.net/) can be leveraged to support data movement, caching, and mirroring between DOE user facilities, thereby enabling collaborative scientific research among facility users, as well as novel combinations of experimental techniques.

Contact: Thiyaga P. Thiyagarajan, 301-903-9706, P.Thiyagarajan@science.doe.gov

18e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Thiyaga P. Thiyagarajan, 301-903-9706, P.Thiyagarajan@science.doe.gov

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19. NOVEL MEMBRANE AND ELECTROLYTE DEVELOPMENT FOR REDOX FLOW BATTERIES

The projected doubling of world energy consumption within the next 50 years, along with environmental concerns about using fossil fuels and the resource constrains, have spurred great interest in generating electrical energy from renewable sources such as wind and solar. The variable and stochastic nature of renewable sources however makes solar and wind power difficult to manage, especially at high levels of penetration. To effectively use the intermittent renewable energy and enable its delivery demand electrical energy storage (EES). For example, storage operating near an intermittent, renewable wind energy source can smooth out wind variability, lessen the slope on ramp rates, and, if of sufficient scale, can store off peak wind energy. EES is also an effective tool to improve the reliability, stability, and efficiency of the future electrical grid, i.e. smart grid that enables real-time, two-way communication to balance demand and supports plug-in electrical vehicles. Electrical energy storage can shave the peaks from a user or utility load profile, increase asset utilization by improving duty factor and delaying utility upgrades, decrease fossil fuel use for ancillary services, provide high levels of power quality, while increasing grid stability. Distributed energy storage near load centers can reduce congestion on both the distribution and transmission systems.

Among the most promising electrical storage technologies are redox flow batteries (RFBs), which stores electrical energy in two soluble redox couples contained in external electrolyte tanks sized in accordance with application requirements. Liquid electrolytes are pumped from storage tanks to flow-through electrodes, where chemical energy is converted to electrical energy (discharge) or vice versa (charge). Between the anode and cathode compartments is a membrane that selectively allows cross-transport of non-active species (e.g., H^+, Na^+, etc.) to maintain electrical neutrality and electrolyte balance. Unlike traditional batteries that store energy in electrodes, RFBs are more like regenerative fuel cells in which the chemical energy in the incoming fuels is converted into electricity at the electrodes. As such the power and energy capacity of a RFB system can be designed separately. The power (kW) of the system is determined by the size of the electrodes and the number of cells in a stack, whereas the energy storage capacity (kWh) is determined by the concentration and volume of the electrolyte. Both energy and power can be easily adjusted for storage from a few hours to days or even weeks, depending on the application, which is another important advantage for the renewable integration. Simplicity in cell and stack structure allows for building large systems based on module design, which is another important advantage for electrical grid applications. Also, the liquid electrolyte and intimate interfaces with electrodes make quick response (in a matter of sub-seconds) possible for utility applications.

Varied RFBs have been developed, including iron/chromium flow batteries, all vanadium redox flow batteries (VRFBs or VRBs), zinc/bromine flow batteries, polysulphide/ bromine flow batteries (PSBs), etc. With all the stated advantages and the successful demonstration of systems up to MWh levels, all RFB technologies have, however, not seen broad market penetration. This is due to, in part, a high life cycle cost (¢/kWh/cycle) that depends on materials/components and performance parameters including reliability, cycle/calendar life, energy efficiency, system energy capacity, etc. Two costly components are membranes and electrolytes that also affect

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efficiency, energy density and other performance parameters. With this in mind, research efforts related to novel membranes and electrolytes for RFB are sought.

Grant applications are sought in the following sub-topics:

19a. Cost Effective, Highly Selective Membranes

Membrane in RFB systems is one of the key components, which serves as a separator to prevent cross-mixing of the positive and negative half-cell electrolytes, while allowing the transport of charge balancing ions (such as H^+, SO_4^{2-} and HSO_4^-) to complete the circuit. An ideal membrane for VRB should exhibit: 1) low permeation rates of the vanadium ions to minimize self-discharge, 2) low area resistance to minimize losses in internal energy, 3) good chemical stability for long lifetime cycling, 4) high ion conductivity for the transport of the charge-carrying ions to maintain the circuit, and 5) low cost. Grant applications are sought to develop low cost, robust proton membrane that can demonstrate satisfactory properties for RFBs, while being more cost-effective than the current technologies. The membrane can be either cationic or anionic for a specific redox flow chemistry.

Contact: Imre Gyuk, 202-586-1482, imre.gyuk@hq.doe.gov

19b. Cost effective, high energy capacity liquid electrolytes

Liquid electrolyte in RFB serves as a “fuel” to store electricity via redox reactions when flowing through electrodes. The liquid electrolyte determines the energy capacity and is a main component to the overall capital cost and technical performance. Take all vanadium RFBs as example. The current electrolytes in vanadium sulfates account for nearly 40% of the total cost of a 1MW/8MWh all vanadium system. The energy capacity is limited by the solubility of vanadium chemicals in the aqueous sulfates. When the vanadium concentration is over 2 M, the electrolytes will become super saturated, resulting in the formation of precipitation for V^{5+} at the temperatures above 40 °C and for V^{2+}, V^{3+}, V^{4+} at the temperatures below 10 °C. When the concentration reaches up to 2.5 M, the solution of V^{5+} precipitates even at room temperature in several days. An ideal electrolyte should demonstrate: 1) high solubility of active components and stability over broad operating conditions, 2) excellent electrochemical reversibility, 3) good chemical compatibility to adjacent components such as electrodes, tubes, etc. 4) acceptance to environment, and 5) most of all, low cost. Grant applications are sought to develop novel electrolytes that satisfy all the aforementioned requirements.

Contact: Imre Gyuk, 202-586-1482, imre.gyuk@hq.doe.gov

19c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Imre Gyuk, 202-586-1482, imre.gyuk@hq.doe.gov

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20. HIGH PERFORMANCE MATERIALS FOR NUCLEAR APPLICATION

The Department of Energy is seeking to advance engineering materials for service in nuclear reactors.

Grant applications are sought in the following subtopics:

20a. Specialty Steels

Grant applications are sought to develop radiation resistant steels, ferritic-martensitic (FM) steels, and Oxide Dispersion Strengthened (ODS) steels that can be used in liquid metal reactors at 400-750°C, have improved creep strength, and can be formed and welded. Grant applications also are sought to improve the weldability and formability of FM and ODS steels, develop methods to monitor i*n situ* irradiation performance in these materials, and develop improved non-destructive evaluation techniques.

Contact: Sue Lesica, 301-903-8755, sue.lesica@hq.doe.gov

20b. Refractory, Ceramic, Ceramic Composite, Graphitic, or Coated Materials

Grant applications are sought to develop refractory, ceramic, ceramic composite, graphitic, or coated materials that can be used in the Generation IV Advanced Gas Cooled Reactors Next Generation Nuclear Plant (NGNP) at temperatures above 900°C in a thermal neutron spectrum environment during normal operations and accidents. These ceramics, graphitic, or coated materials should have the following characteristics: (1) low thermal expansion coefficients, (2) excellent high-temperature strength, (3) excellent high-temperature creep resistance, (4) good thermal conductivity, (5) ability to endure a high-neutron-fluence environment, (6) ability to be easily fabricated, (7) capable of being joined, (8) low erosion properties in flowing helium, and (9) ability to survive air and/or water ingress accidents. Because high temperature strength and corrosion resistance may be difficult to achieve with a single material, composite or coated systems may be required.

In addition, grant applications are sought to develop methods for real-time *in situ* monitoring of the irradiation performance of these NGNP refractory, ceramic, graphitic, and coated composite materials. Approaches of interest include the development of sensors that can monitor the mechanical properties of these materials during their service lifetime and during large temperature changes.

Contact: Sue Lesica, 301-903-8755, sue.lesica@hq.doe.gov

20c. Assessment and Mitigation of Materials Degradation

Grant applications are sought to develop technologies for the assessment and mitigation of materials degradation in Light Water Reactor systems and components, in order to extend the service life of current light water reactors. Approaches of interest include (1) advanced *in situ* techniques for the monitoring of swelling in stainless steel, hardening of reactor pressure vessels, and the degradation of concrete; (2) new welding techniques for component repair; (3) methods that can mitigate or predict
irradiation and aging effects in reactors and components, and (4) improved nuclear fuel cladding materials.

Contact: Sue Lesica, 301-903-8755, sue.lesica@hq.doe.gov

20d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Sue Lesica, 301-903-8755, sue.lesica@hq.doe.gov

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3. "Light Waster Reactor Sustainability" U.S. DOER Office of Nuclear Energy Website (URL: http://www.nuclear.gov/LWRSP/overview.html)

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21. ADVANCED COAL RESEARCH

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from hydrocarbon fuels. In supplying this energy need, however, the Nation must address growing global and regional environmental concerns, supply issues, and energy prices. Maintaining low-cost energy in the face of growing demand, diminishing supply, and increasing environmental pressure requires new technologies and diversified energy supplies. These technologies must allow the Nation to use all of its indigenous resources more wisely, cleanly, and efficiently. These resources include the Nation's most abundant and lowest cost resource, coal.

Grant applications are sought in the following subtopics:

21a. Carbon Dioxide (CO2) Conversion to Fuels and Chemicals

Utilization of carbon dioxide (CO2) has become an important global issue due to the significant and continuous rise in atmospheric CO2 concentrations, accelerated growth in the consumption of carbon-based energy worldwide, depletion of carbon-based energy resources, and low efficiency in current energy systems. Therefore, grant applications are sought to develop novel concepts, based on the use of advanced catalysts, for the conversion of CO2 from energy production and utilization systems to value-added fuels and industrial chemicals. Biomimetic processes will be given special consideration. Proposed approaches must be novel and innovative, show clear economic advantages over the existing state of the art, and provide the data needed to demonstrate the CO2 conversion, the projected economics, and the commercial feasibility.

Contact: Doug Archer, 301-903-9443, douglas.archer@hq.doe.gov

21b. Oxidation of Coal to Value-added Chemicals and Fuels

Continued U.S. dependence on foreign oil has increased interest in domestic coal supplies as feedstocks for liquid fuels and chemicals. Considerable research and development has been directed towards direct and indirect coal liquefaction. In addition, there have been previous studies in mild oxidation to convert coal to chemicals by breaking the coal molecules using an oxidant such that a high proportion of the coal can be converted into condensed products with significant commercial value. Potential products have included low molecular weight aliphatic and mono-aromatic compounds including aromatic acids, poly-acids, phenols, and short chain aliphatic acids and diacids including carboxylic acids (formic, acetic, oxalic, malonic, and succinic). Sub-critical water decomposition can result in significant quantities of dissolved benzene and methanol. These have potential as chemical feedstock or fuels/fuel precursors. Proposed approaches must be novel and innovative and show clear economic advantages over the existing state of the art. Economics depend largely on processing cost, conversion, and high-value product yield and separation. Grant applications are sought to continue the evolution of processes for the oxidation of coal to commercial chemicals and fuels utilizing catalysts to improve yield and selectivity and accounting for each of the following steps: (1) a preliminary identification of the process, (2) a preliminary economic analysis, and (3) a more detailed study of the selected process(es) leading to commercialization.

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Contact: Doug Archer, 301-903-9443, douglas.archer@hq.doe.gov

21c. Solid Oxide Fuel Cell Cathode Enhancement Through Infiltration Techniques

Research is sought that employs infiltration processing techniques to develop enhanced performance solid oxide fuel cell (SOFC) cathodes operating at 650^o to 850^{o}C. The new techniques might involve new materials infiltrated to provide catalytic enhancement or new nano-structures that enhance the transport and surface activity of existing materials. These structures and their electrochemical performance must be stable for greater than 40,000 hrs, under load, at high temperature. Techniques should be amenable for implementation in state-of-the-art, YSZ-based (as opposed to ceria-, LSGM-, or Bi- based), cell architectures either before or after stack assembly. Grant applications should include a description of how an anticipated structure will lead to enhanced performance and have sufficient analysis of the proposed manufacturing process to evaluate potential cost and complexity. In particular, evaluations of structural and performance stability over extended periods of time are encouraged.

Background:
SOFC cathodes consist of an optimized structure involving ion, electron, and gas conduction paths. The nexus of these paths results in electrochemical charge transfer yielding a steadily polarized electrode which drives the electrical current through the external power load. The charge transfer process can be enhanced by a high density of reaction sites, by catalytic activation of reaction species, and by high conductivity to and from the reaction sites of all species involved.

High performance cathodes to date involve a heterogeneous mixture of materials in a combination that provides all of the necessary transport and reaction functions. These materials are mixed together and sintered into individual functional layers or co-sintered together with adjacent layers/components to form a cell (anode|electrolyte|cathode). Typical cathodes consist of LSM-YSZ or LSCF.

Undesirable chemical reactions between the different materials in such composite structures can occur during high temperature processing and limit the ability to use more catalytically active materials. An alternative to co-sintering of particles in the composite is to first process a porous sintered support structure at higher sintering temperatures and then create active nano-structural additions and modifications through chemical infiltration and thermal processing at reduced temperatures. In this manner, unique microstructures can be created and deleterious interfacial reactions avoided.

Contact: Briggs White, 304-285-5437, briggs.white@netl.doe.gov

21d. Self-Powered (energy harvesting) Wireless Sensors for High Temperature Environments in Fossil Energy Power Systems

An engineered, self-powered wireless package with an integrated protective housing for commercial installations of new sensor technology in high temperature environments is sought for development. Primary applications where the sensors would be applied are Fossil Fuel-based power plants including coal-fired boiler systems, coal gasification systems, and turbines.

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Interested applicants should focus on one type of Fossil Fuel power system so that the design can meet the specifications and requirements of that power system. Successful applicants should reflect an understanding the Fossil Fuel based power system of interest in order to devise a suitable design. Descriptions of the Fossil Fuel based power systems can be found at www.netl.doe.gov and www.fe.doe.gov.

The Department of Energy, other government agencies, and sensor developers have put forth a significant effort to develop a variety of new sensor technology that can function reliably and accurately in high temperature environments (500oC-1500oC). Ceramic based micro sensors and optical sensors are generally the most common types of sensors suitable for these environments. Many of these prototype sensors are progressing to the point where long term or large scale testing is necessary to assess the commercial viability of the design. However, much effort is expended on how best to package and protect the sensors from harsh environment while allowing exposure of the sensor in a quasi in-situ approach.

Grant applications are sought for the development of highly capable sensor package that can self-power and wirelessly communicate data from the sensor to a suitable hub/node. The sensor packaging needs to consider the high temperature environment in which the sensor must function and provide adequate protection support survivability of the sensor. Packaging designs must consider proper selection of high temperature materials, appropriate size, ease of installation through standard process ports or couplings, and ease in accessing or replacing the sensors. The power required to operate the sensor (through various energy harvesting technologies) and means by which the data can be wirelessly transmitted must also be accounted for in the approach.

Contact: Regis Conrad, 301-903-2827, regis.conrad@hq.doe.gov

21e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Doug Archer, 301-903-9443, douglas.archer@hq.doe.gov

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Subtopic c:

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22. ADVANCED FOSSIL ENERGY RESEARCH

The Advanced Research (AR) program within NETL's Office of Coal and Power Systems fosters the development of innovative, cost-effective technologies for improving the efficiency and environmental performance of advanced coal and power systems. In addition, AR bridges the gap between fundamental research into technology alternatives and applied research aimed at scale-up, deployment, and commercialization of the most promising technologies identified. The AR program encompasses three major subprograms: Sensors and Controls Innovations; High Performance Materials; and Computational Energy Sciences.

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from the Nation's most abundant and lowest cost resource, coal. Maintaining low-cost energy in the face of growing demand and increasing environmental pressures requires new technologies that will enable higher efficiency. The implementation of sensors and advanced controls in power systems can provide valuable methods to improve operational efficiency, reduce emissions, and lower operating costs. These sensors and controls must provide reliable and consistent data, longevity of use, and ease of calibration. However, it has been a challenge to develop sensors and controls that are able to endure the harsh environments associated with advanced power systems. This environment includes high temperatures (800-1500°C), high pressures (500-1000 psi), and corrosion due to abrasive materials.

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High performance materials research cuts across many scientific and technological disciplines to address materials requirements for all fossil energy systems, including innovative advanced power systems. The goal is to bridge the gap between basic and applied research, often by pursuing "breakthrough" concepts based on mechanistic understanding from any discipline to develop materials with unique thermal, chemical, and mechanical capabilities.

Grant applications are sought in the following subtopics:

22a. Novel Approaches for Monitoring the Condition of Advanced Power Plants
Novel approaches are sought for the development and design of on-line instrumentation and sensors capable of monitoring the state of critical equipment and components within an advanced power plant. Instrumentation and sensors capable of monitoring in high temperature harsh environments for the measurement of stress/strain, corrosion, blade tip clearance/deflection, thermal barrier coating wear, fouling, and/or material fatigue/cracking are of interest. New approaches to embedded sensor designs or non-destructive evaluation (NDE) techniques are of interest along with wireless data communication capabilities. Development and utilization of other types of measurements are also of interest for the creation of a network of condition monitoring sensors. Employing robust sensing networks will enable the development or use of algorithms and models for the prediction of equipment/component maintenance, remaining life and failure. Predictive algorithms and models should be considered an integral part of a robust condition monitoring system. Equipment that could potentially benefit from the development of advanced condition monitoring approaches include coal gasifiers, turbines, advanced coal combustion systems, and other critical or high maintenance equipment commonly employed in energy and power generation systems.

Grant applications are sought for condition monitoring sensors capable of function in high temperature (800 ^{o}C-1200 ^{o}C) harsh environment that will directly contribute to improving system control, protect capital equipment investment, and promote safety through prevention of catastrophic equipment failure. Non destructive and embedded techniques are of interest along with wireless communication capability.

Contact: Susan Maley, 304-285-1321, susan.maley@netl.doe.gov

22b. Advanced Process Control Techniques using Distributed Intelligence
As new power generation technologies and systems mature, the plant which encompasses these systems will become inherently complex. In order to manage complexity, the process control architecture that supports the system will need to evolve to manage the complexity and achieve the goal of optimum performance. Research and development are being performed on novel control architectures that capitalize on computational capability and the ability to distribute this capability to the lower level where sensing and actuation are occurring in real time. These approaches depart from the traditional centralized control architectures and introduce concepts where networked communication of information (not data) and decision making capability at the lower levels enable intelligence to be distributed and the sensing and actuation network to function in a self organizing manner. The topic seeks to expand on and integrate the various concepts using realistic system level scenarios and case studies. Phase I seeks to develop viable

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concepts for distributing intelligence for process control followed by Phase II development of the appropriate software and hardware to enable demonstration the novel concepts.

Grant applications are sought for the development of novel process control technique that distribute intelligence to the actuaion and sensing level with a system Phase I seeks to develop viable concepts in these areas and those concepts which include self organization, adaptive control, model based techniques, and data mining capability that can be distributed with a realistic sensing and actuation network to enable distributed intelligent control are encouraged.

Contact: Susan Maley, 304-285-1321, susan.maley@netl.doe.gov

22c. High Performance Materials for Long Term Fossil Energy Applications
New materials, ideas, and concepts are required to significantly improve performance and reduce the costs of existing fossil energy power generation systems or to enable the development of new systems and capabilities. The Fossil Energy Materials Program conducts research and development on high-performance materials for longer-term fossil energy applications. The program is concerned with operation in the hostile conditions created when fossil fuels are converted to energy. These conditions include high temperatures, elevated pressures, and corrosive environments (reducing conditions, gaseous alkali). Examples of such environments are:

Combustion gas turbines in IGCC cycles that are being designed to operate in both H_2 and CO/H_2 environments at inlet temperatures up to 1700 deg C and pressures to 650 psi
Advanced ultrasupercritical (AUSC) steam power plant cycles operating at steam conditions of 760 deg C and 5000 psi.

Oxy-fueled combustion systems where components will be exposed to CO_2 and CO_2 steam.

Grant applications are sought for the development of materials technology that will enable the deployment of the aforementioned fossil energy power generation technologies in the next 5 – 15 years. This includes:

Development of materials, both structural and functional, that have the potential to improve the performance and/or reduce the cost of the technologies.

Development of a technology base in the synthesis, processing, life-cycle analysis, and performance characterization of advanced materials that are slated to be used in these applications.

Contact: Richard Dunst, 412-386-6694, dunst@netl.doe.gov

22d. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Susan Maley, 304-285-1321, susan.maley@netl.doe.gov

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3. White, Tony, "Expert Assessment of Stigmery: A report for the Department of National Defense" Defense Research and Development Canada, Contract Report DRDC CR 2005-004, citeseerx.ist.psu.edu/viewdoc/download, October 2005

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23. CLIMATE CONTROL TECHNOLOGIES FOR FOSSIL ENERGY APPLICATIONS

This topic addresses carbon dioxide (CO_2) emissions and its management for climate control. Starting with the industrial age, the combustion of carbon-based fossil fuels has raised global emissions of CO_2 compared to levels two centuries ago. A large body of scientific evidence points to the recent build-up of CO_2 and other greenhouse gases (GHG) in the atmosphere worldwide as a contributing factor to global warming. This build-up could lead to future significant global climate imbalances and adverse consequences for human health and welfare. Strategies to reduce GHG include CO_2 capture from large stationary industrial emitters; geologic storage of CO_2; and the reuse of CO_2 for chemical, manufacturing, petroleum, and other applications. Significant research is currently being pursued for new technologies that will advance implementation of carbon capture and sequestration (CCS) technologies, along with alternative uses of CO_2 for industrial applications.

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Grant applications are sought in the following subtopics:

23a. Advanced Solvents for CO2 Capture from Existing Coal-fired Power Plants
Significant research and development is currently being pursued for new technologies to separate and capture CO_2 from flue gas streams produced by existing coal-fired electric generating power plants. Aqueous amine absorption is the state of- the-art technology for post-combustion CO_2 capture from flue gas. However, amine absorption has a number of drawbacks, including significant capital and operating costs. Therefore, grant applications are sought to develop solvent based technologies that can substantially lower the cost of CO_2 capture from flue gas produced by existing coal-fired power plants. Incremental improvements on amine-based systems are not sought. The research effort should demonstrate the viability of the technology to perform with actual flue gas compositions generated from existing coal-fired power plants. Technologies should be capable of 90% or greater reduction in CO_2 emissions per net kWh and result in less than a 30% increase in the cost of energy services.

Solvent-based systems, typically using amines, are in commercial use in scrubbing CO_2 from industrial flue gases and process gases. However, they have not been applied to removing large volumes of CO_2 as would be encountered in a PC-fired utility boiler flue gas. Key technical challenges to solvent based systems for capturing CO_2 from coal-fired power plants include: (1) large flue gas volume; (2) relatively low CO_2 concentration; (3) flue gas contaminants; and (4) high parasitic power demand for solvent recovery. The liquid and gas are typically contacted in a countercurrent packed column or a spray tower. Commercial CO_2 capture solvents are typically amine-based. In responding to this subtopic applicants should demonstrate a thorough understanding of the technology being proposed. The applicant should provide information relevant to overcoming the technical challenges identified above in achieving the DOE goal. The applicant should also provide a description all auxiliary power required, theoretical maximum CO_2 capacity and target working capacity (in lb CO_2/lb solution), description of the stripper configuration, information about the chemical and thermal stability of the solvent, the chemical reactions for the CO_2 absorption/regeneration cycle (and if available, kinetic data, expected operating temperatures, theoretical regeneration energy, and target regeneration energy as a function of working capacity), the solvent composition and anticipated cost range (if manufactured in large quantities), the solvent molecular weight or average molecular weight (mixed solvents) and the boiling point of the solvent (or solvents if mixed solvents). Since this subtopic deals with capture from an existing coal-fired power plant, applicants should include a block flow diagram of how their technology would be retrofitted to a typical pulverized coal fired power plant.

Contact: Andy Aurelio, 304-285-0244, Isaac.Aurelio@netl.doe.gov

23b. Dense Carbon Dioxide Transport Membranes
Pre-Combustion carbon capture is primarily applicable gasification plants where coal is gasified with water and controlled amount of oxygen to produce synthesis gas (syngas), a mixture of carbon monoxide (CO) and hydrogen (H_2). The syngas is next sent to water gas shift (WGS) reactor where it is reacted with water to form syngas gas shift, which is mixture of carbon

dioxide (CO_2) and hydrogen. H_2 or CO_2 is separated from the syngas shift mixture for producing hydrogen and capture-ready CO_2 for safe storage.

Applications are invited for dense CO_2 transport membranes. Studies involving novel dense CO_2 transport membrane material formulation, synthesis, characterization, and proof-of-principle scale permeation tests are included. Computational methods offer a cost-effective technique to engineer novel materials and computational approaches to design novel dense CO_2 perm-selective membranes are encouraged. Dense CO_2 transport membranes are expected to operate at WGS reactor outlet conditions. Polymeric CO_2 separation membranes and hydrogen transport membrane R&D for separating hydrogen from syngas shifts are specifically excluded from considerations.

Contact: Arun Bose, 412-386-4467, arun.bose@netl.doe.gov

23c. CO2 Utilization for Chemicals and Solid Products

As high-CO_2-emitting utilities and other industries move toward CO_2 capture technologies to manage greenhouse gas emissions, more and more CO_2 will become available as a resource for multiple applications. In addition, geologic sequestration may not be an option for the storage of CO_2 in some areas of the country. Therefore, grant applications are sought to develop novel technologies for the use of captured CO_2 as a feedstock for chemical synthesis into valuable products. *Algae use and synthesis to fuels is addressed in other Program areas and is not of interest for this subtopic. Grant applications using these approaches will be declined. Synthesis to carbon monoxide is also not of interest for this subtopic unless it is produced as an intermediary and consumed in the proposed process.* Approaches of interest include (1) the development of technologies for chemical conversion of CO_2 into marketable products that do not easily convert back to CO_2, and (2) the utilization of significant quantities of CO_2 in processes within the chemical industry. The research effort should demonstrate that the proposed process will not produce more CO_2 than is utilized. Applicants are encouraged to propose technologies that utilize CO_2 at its source.

Contact: Darin Damiani, 304-285-4398, darin.damiani@netl.doe.gov

23d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Andy Aurelio, 304-285-0244, Isaac.Aurelio@netl.doe.gov

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1. Carbon Sequestration Technology Roadmap and Program Plan – 2007, U.S. DOE National Energy Technology Laboratory (NETL), May 2007. (Full-text available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/project%20portfolio/2007/2007Roadmap.pdf)

2. Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage: Chapter 7 – Mineral Carbonation and Industrial Uses of Carbon Dioxide, 2005, Metz, B., Davidson, O., de Coninck, H., Loos, M., and Meyer, L. (editors), Cambridge University Press, p. 319-337. (Full text available at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports_carbon_dioxide.htm)

24. COAL GASIFICATION TECHNOLOGIES

Coal gasification produces synthesis gas (primarily a mixture of H_2 and CO), which can be converted into electricity, hydrogen, substitute natural gas, and other clean fuels, as well as high-value chemicals to meet specific market needs. Furthermore, while other sources of power may fluctuate, gasification systems operate on the low-cost, widely available, domestic feedstock of coal, and can be run on coal-biomass mixtures. By using coal to make hydrogen or methane, coal can be converted into clean fuels, with a much smaller carbon footprint than typical for coal combustion. For instance, a power plant run on clean hydrogen will only produce water as the flue gas.

The U.S. Department of Energy‘s Office of Fossil Energy, through its National Energy Technology Laboratory, seeks to enhance the performance of gasification systems to make them cost competitive with alternative processes (e.g., pulverized coal power generation, natural gas combined cycle), thus enticing U.S. industry to implement the environmentally superior gasification-based processes. The enhancements sought will improve economics, improve gasification plant efficiency, improve process environmental performance (including carbon emission reduction), and increase process reliability.

Grant applications are sought in the following subtopics:

24a. CO2 – Coal Slurry Preparation

A CO_2-coal slurry feed in a gasification process may have significant efficiency and cost advantages over a water slurry feed due to the lower heat of vaporization, and lower viscosity and surface tension. This could be especially true for high moisture coal, since moisture may not have to be removed from the coal prior to mixing with CO_2. In addition, higher solids loadings

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are feasible when using liquid CO_2 as the slurry medium than when using water. Also, using CO_2 coal slurry will allow gasification plants with CO_2 capture to operate more efficiently.

For more background information on this concept, see the ERPI report 1014432 "Program on Technology Innovation: Advanced Concepts in Slurry-Fed Low-Rank Coal Gasification"[1]:

Grant applications are sought to optimize the coal-CO_2 slurry process from slurry preparation to readiness for gasifier injection (at least 750 psi), including necessary rheological testing not available in the literature, process tests and/or needed equipment design and construction. The coal used shall be Sub-Bituminous or Lignite (moisture level of at least 30 percent), with a particle size distribution typical of a standard power plant grind (a fineness of 70% passing through 200 mesh [74 microns])[2] or better is traditionally required. The CO_2 purity shall be typical of pipeline specifications[3].

The proposal must adequately describe the benefits anticipated from the novel process, novel additives (to avoid rapid settlement and agglomerations) for long-term stability of CO_2 slurry, and new/modified equipment. Sufficient data shall be provided for the National Energy Technology Laboratory (NETL) personnel to be able to conduct a benefits analysis to confirm the overall reduction in capital costs, and cost of hydrogen or power production. In addition, a variety of sub-bituminous or lignite coal must be tested to determine their slurry ability The proposal needs to include an overview of the whole process, from raw feed materials to gasifier injection, and how the proposed process/equipment fits into it. The work plan should include small scale tests to determine the minimum coal drying necessary and maximum solid loading, and plans to resolve process or materials of construction issues with higher moisture levels.

Contact: Dave Lyons, 304-285-4379, k.david.lyons@netl.doe.gov

24b. Novel Concepts in Air Separation (non-membrane, non-sorbent, and non-redox)
The most prominent technology for producing the large volumes of oxygen needed for an Integrated Gasification Combined Cycle (IGCC) plant is the cryogenic air separation unit (ASU). However, this technology is both capital and energy intensive, consuming 10-15 percent of the gross power output of an Integrated Gasification Combined Cycle (IGCC) power plant and accounting for as much as 12-15 percent of its cost (around $120 -$170/kW). Also, there have been availability concerns related to the application of this technology to IGCC.

Lower cost oxygen separation systems will increase the potential for broad implementation of oxygen-blown IGCC projects in the U.S. Therefore, there is an obvious need to develop new air separation processes or to improve upon existing cryogenic air separation systems that reduce costs and improve performance and availability. The National Energy Technology Laboratory (NETL) is currently developing advanced air separation technologies that can produce commercial-scale quantities of oxygen at lower cost than conventional cryogenic systems; however, NETL's efforts are primarily focused on ion transport membranes (ITM).

Grant applications are sought to improve upon the existing cryogenic air separation technology or to develop new concepts (non-membrane, non-sorbent, and non-redox) for the separation of oxygen from air.

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Areas of potential research interest include: (1) advancements to the existing cryogenic ASU technologies, in order to improve the cost, performance, and/or availability; and (2) other novel concepts capable of advancing non-membrane, non-sorbent, and non-redox separation processes to produce oxygen in volumes sufficient for IGCC plant operations, at relevant purities, and in an efficient, cost-effective manner. DOE is also interested in improving the availability of the cryogenic ASU technologies. Specific areas of potential study include but not limited to: Air compressor inlet guide vanes, electric motor drive, rotor, and instrumentation; Direct contact cooler; Molecular sieve valve selection and regeneration heater; Cold box leakages; and Liquid oxygen storage. Grant applications must describe the potential performance and economic advantage - in an IGCC plant - of the proposed approach over conventional cryogenic air separation processes.

Contact: Arun Bose, 412-386-4467, arun.bose@netl.doe.gov

24c. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Dave Lyons, 304-285-4379, k.david.lyons@netl.doe.gov

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3. http://www.netl.doe.gov/technologies/carbon_seq/Resources/Analysis/pubs/CO2CaptureGuidelines.pdf page 13.

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25. TECHNOLOGIES FOR CLEAN FUELS AND HYDROGEN FROM COAL

The Hydrogen and Clean Coal Fuels Program supports DOE's strategic goals – increasing energy security, reducing the environmental impact of energy use, promoting economic development, and encouraging scientific discovery and innovation – by researching and developing novel technologies for the economic conversion of coal, America's largest domestic fossil energy resource, into hydrogen and other clean fuels. With carbon management and/or capture and storage, coal can produce these fuels in a manner that addresses concerns regarding the build-up of atmospheric carbon dioxide concentrations. Coal resources offer an attractive option for producing hydrogen that can be utilized for power generation or transportation. Hydrogen-rich liquids and substitute natural gas (SNG) can be produced from coal and used directly or as an alternative route to hydrogen production. Additionally, innovative technologies and methods to produce, deliver, and utilize hydrogen from coal will provide a clean and sustainable alternative to imported fuels.

Grant applications are sought in the following subtopics:

25a. Concepts for Enhanced Catalysts for Water-Gas-Shift and Fischer-Tropsch Processes for Gases from Co-Mingled Coal and Biomass Gasification

Recent systems studies have shown that the addition of biomass to a coal gasification feedstock would be beneficial. This process, known as the Coal-Biomass-to-Liquids (CBTL) process employs domestic coal and biomass feedstocks, has a better greenhouse gas footprint than conventional processes for petroleum fuels, and is projected to be economically competitive at a world oil price significantly below $100 per barrel. Improvements to several plant unit operations offer particular opportunities. For example, the use of water-gas shift (WGS) and Fischer-Tropsch (FT) technologies are well-known for converting syngas to high hydrogen content liquids. However, the current commercial catalysts used in WGS processes and FT syntheses are intrinsically sensitive to small amounts of poisons. In commercial operation, these catalysts must be replaced or regenerated after a certain operational period. The specifics of this syngas cleaning are based on economic considerations: the investment in gas cleaning must be weighed against decreased production due to catalyst poisoning. Therefore, new or novel catalysts that are resistant to contaminants may aid in the overall cost of the produced liquid fuel. These syngas contaminants, which result from the gasification of co-mingled coal and biomass, include (1) sulfur species, trace toxic metals, halides, and nitrogen species from coal, and (2) KCl and NaCl from biomass.

Grant applications are sought for novel WGS and/or FT catalysts, or catalyst-related improvements that will result in improved CBTL plant efficiency and/or cost. In addition to the development of catalysts that may be resistant to contaminants, approaches that address other catalyst related challenges are also of interest, provided that the contaminants are removed prior to the WGS or FT process. These challenges include the optimization of overall yields of desired fuel fractions for FT catalysts; improved CO conversion for WGS catalysts; improvements that result in maintenance of sustained catalyst activity; and the need for less costly catalyst materials.

Temperature, pressures, and feed compositions use in experiments should be justified in terms of being relevant for integrating the proposed concept within a CBTL process; that is, the catalysts should be targeted for use in the temperature and pressure ranges of commercial WGS and FT catalysts, or they should be justified (e.g., thermodynamically) for the proposed test conditions. Literature reviews are not within the scope of this subtopic and will be rejected.

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Contact: Jason Hissam, 304-285-0286, jason.hissam@netl.doe.gov

25b. Concepts for Direct Liquefaction of Coal/Biomass Mixtures
Direct liquefaction of co-mingled coal/biomass mixtures has the potential to increase our energy security by making transportation fuels via these abundant domestic resources. In addition, the use of biomass as a feedstock can reduce the carbon footprint of this fuels-manufacturing process. Direct liquefaction processes include high-pressure hydrogenation, reactions with oils that can donate hydrogen, and enzymatic processes. The types of coals that have been used in direct liquefaction include lignite, sub-bituminous, and bituminous. The types of biomass that are available for direct liquefaction include corn stover, wood (forest residue, manufacturing residue, or short-rotation woody crops such as poplar), grass (switchgrass and mixed prairie grasses), and algae.

Grant applications are sought to demonstrate the feasibility of novel concepts for the direct liquefaction of a coal/biomass mixture (or mixtures) from the above-mentioned matrix of available feedstocks. The mixture chosen for research should be based on minimizing the transportation costs of bringing the feedstocks to the liquefaction plant. In addition, the mixture should contain at least 30 wt% (but not more than 50 wt%) biomass (dry basis). The research should be directed toward making transportation fuels at a cost that is competitive with the production of these fuels from petroleum. Literature reviews are not within the scope of this subtopic and will be rejected.

Contact: John Stipanovich, 412-386-6027, John.Stipanovich@netl.doe.gov

25c. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Jason Hissam, 304-285-0286, jason.hissam@netl.doe.gov

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4. Gang Wang et al, "Direct liquefaction of sawdust under syngas with and without catalyst," Chemical Engineering and Processing. Volume 46 Issue 3, March 2007, Pages 187-192.

26. ADVANCED TURBINE TECHNOLOGY FOR IGCC POWER PLANTS

Integrated Gasification Combined Cycle (IGCC) power plants are attractive alternatives to current pulverized coal technologies in large-scale stationary applications. IGCC systems are very efficient, with efficiencies ranging from 35 to 45 percent (depending on system configuration and size). They also are environmentally friendly, emitting lower levels of pollutants and particulates. However, in order to meet long-term Turbine Program goals, which target efficiencies greater than 50%, the inlet temperature may need to be raised even further than the current state-of-the-art (to 1500ºC (2732 ºF) or higher). Therefore, this topic seeks advances in the design and manufacturability of high temperature materials and hot gas path component cooling techniques, two enabling technologies for higher efficiency and lower emissions.

Grant applications are sought in the following subtopics:

26a. Novel Material System Architectures that Operate at Higher Temperatures
Grant applications are sought for research and development to explore new architectures for turbine hot gas path material (coating and substrate) systems.

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Proposed coating architectures must possess a combination of heat resistance, thermal insulation, and oxygen barrier qualities; hot-corrosion and erosion resistance; long fatigue life, resistance to adverse coating/substrate interaction; adhesion capacity; and high-temperature mechanical performance. In order to define a novel coating architecture to address these requirements, approaches of interest should (1) consist of metallic and/or ceramic components; (2) optimize thermal insulation without sacrificing strain tolerance or temperature capability; and (3) ensure a reliable coating architecture with a surface temperature capability approaching 1425°C for a minimum of 8,000 hrs.

The included advanced substrates must (1) have high strength at elevated temperatures; (2) withstand the high thermal, creep, and fatigue loads resulting from spallation and/or debonding of the accompanying coating system; (3) provide an adequate level of internal cooling for future high-temperature, high-hydrogen-fired turbine applications; and (4) demonstrate viable extended life (i.e., 8,000-30,000 hrs) in oxidizing environments containing as much as 15-20% H_2O, where surface temperatures range between 1,100-1,500ºC. Materials systems of interest include modified superalloys, refractory metal alloys, and ceramic-based composites designed to meet the performance criteria outlined above.

The proposed R&D applications should address materials-system level performance concerns such as thermal gradients, thermal expansion mismatch, and interdiffusion/chemical compatibility. The new material systems must withstand the temperature cycles that are expected. A complete description of the manufacturing process required to achieve the proposed architectures should be provided to facilitate analysis of potential cost entitlements and implementation complexity. Applications can focus on individual components; however, a clear plan should be presented outlining how entire substrate, coating architectures would be fabricated, implemented, and perform.

Contact: Robin Ames, 304-285-0978, robin.ames@netl.doe.gov

26b. Rapid Manufacturing and Prototyping of Gas Turbine Components

Rapid prototyping (including layer manufacturing techniques), and manufacturing can greatly reduce the cycle time to produce parts for initial testing and verification of industrial gas turbine components. Here "rapid" is being used to mean any technique that does not involve making tooling or molds. Today's state of art processes, such as 3D printing (stereo lithography), laser sintering, etc. are generally used for facsimile parts, where dimensional accuracy and material properties may be compromised when compared to production components. To this end, rapid prototype parts, such as those manufactured by powder metallurgy, cannot currently replace production parts in gas turbines even if they are compositionally identical. In addition, some rapid prototyping technologies can be expensive and this cost limits the applicability to production and number of iterations which could potentially be explored throughout a development process. Therefore, grant applications are sought for research and development to explore innovative approaches to increase the density and mechanical properties of complex parts for high-temperature gas turbine applications. Reductions in machine and material costs combined with increases in machine throughput and improved laser manufacturing technique (LMT) material properties are important steps for rapid manufacturing components to compete with their molded counterparts as an efficient production process with end use in mind.

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Grant applications must provide reliable data and processes for high temperature capable rapid manufactured materials (like powder metallurgy or ceramics, i.e. aluminum oxide) with key requirements including minimizing porosity and ability to maintain tight tolerances (+/- 0.001") for critical part dimensions. Applicants can also focus on the application of rapid prototyping methodology to current state of the art manufacturing processes to significantly reduce the overall time and cost to market, thereby reducing manufacturing energy usage and the associated carbon footprint.

Contact: Robin Ames, 304-285-0978, robin.ames@netl.doe.gov

26c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Robin Ames, 304-285-0978, robin.ames@netl.doe.gov

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27. FUEL CELL TECHNOLOGIES FOR CENTRAL POWER GENERATION WITH COAL

Improved power generation technologies will help the nation make more efficient, cost-effective and environmentally-responsible use of its abundant domestic coal reserves. This topic seeks advances in fuel cell technology for central coal power plants.

Solid oxide fuel cell (SOFC)-based systems are attractive alternatives to current technologies for coal-fueled central generation. SOFC systems are very efficient, with efficiencies ranging from 40 to over 60 percent (depending on system configuration). Electrochemical conversion in a SOFC takes place at lower temperatures (650ºC to 850ºC) than combustion-based technologies, resulting in decreased emissions, particularly nitrogen oxides. Furthermore, in a carbon-constrained world, SOFCs offer considerable opportunities with respect to both lower CO_2 generation (as a result of higher efficiency) and increased CO_2 capture. With these advantages, systems containing improved fuel cell technology, in combination with heat recovery subsystems and commercial CO_2 capture technology, will meet DOE goals that include 45-50% efficiency (coal HHV to electrical power), <2ppm NOx, and 90% carbon capture. Consistent with these goals, the DOE-sponsored Solid State Energy Conversion Alliance (SECA) will develop commercially-viable ($700/kW) SOFC power generation systems.

Grant applications are sought in the following subtopics.

27a. Cathode Blowers and Anode-Recycle Blowers for SOFC Systems
SOFC-based power systems for coal-fueled central generation applications require efficient and reliable blowers to ensure protection of the SOFC stacks and to maximize system efficiency. Cathode blowers provide the air that serves as the SOFC oxidant and removes heat from the stacks. With respect to the anode recycle blower, it is desirable to recycle a portion of the water-rich anode effluent back to the anode inlet in order to maintain an acceptable steam to carbon ratio.

Applications are sought to develop either or both of these devices for a ~250kW - 1MW SOFC system. Specific blower performance specifications will be dependent upon the design of the SOFC system with which it is associated; nevertheless, the following representative nominal

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requirements, in lieu of design-specific data, are provided and should be addressed within the grant application:

- The working fluid is atmospheric air for cathode blowers and high-temperature (750-800C) anode effluent (primarily CO_2 and H_20, with some residual H_2) for anode recycle blowers.
- The unit should be capable of variable speed control.
- In the case of the anode recycle blower, the blower shaft seal shall be designed so as to prevent gas leakage, and provisions shall be made to include a way to drain water from anode-recycle blower during extended shutdowns.
- The blower unit must have a design life of 40,000 hours, with a 100% duty cycle and 10,000 hour maintenance interval.
- The issue of contamination of the working fluid (e.g., the introduction of grease or oil) must be addressed, as the introduction of foreign matter may have an adverse effect on the SOFC stack.

Applicants are encouraged to consult with the SECA Industry Teams with respect to their respective detailed specifications for this component.

Contact: Maria Reidpath, 304-285-4140, Maria.Reidpath@netl.doe.gov

27b. Low-Cost Megawatt-Scale High-Temperature Heat Exchangers for SOFC Applications

Grant applications are sought to develop novel, high-temperature heat exchanger designs that address the cost and technical performance requirements for cathode air preheaters for use in 250 kW to 1 MW SOFC systems. For this component, the source-side working fluid is post-combustor SOFC stack effluent, with an inlet temperature between 850°C and 1000°C. The sink side is air from the cathode air blower with a temperature as low as minus 40°C. Maximum source and sink side flow rates are approximately 200,000 slpm. Due to the parasitic losses associated with the cathode air blower and the resultant adverse impact upon system efficiency, this heat exchanger requires a very low differential pressure drop (1.5 to 2.5 kPa on the sink side; 0.75 to 1.25 kPa on source side) and high effectiveness (≈ 85 to 90%). Although material sets such as nickel-based superalloys (e.g., 600 series Inconels) are currently being used, they are very expensive to manufacture.

Regardless of the proposed design, cost, reliability (tolerant of high steady-state temperatures, internal temperature gradients and thermal cycles) and manufacturability are critical issues that must be addressed within the proposal. Materials identified for incorporation into the design must be analyzed for chemical (e.g., resistance to corrosion and sulfidation attack) and thermomechanical stability (e.g., creep, thermal shock tolerance) in the context of the proposed design and application. Ceramic materials will be considered, provided that any thermal shock and leakage (at manifold interfaces or working fluid crossover) issues can be adequately addressed. The proposed heat exchanger design must have a design life of 40,000 hours, with a 100% duty cycle and 10,000 hour maintenance interval. The unit must be able to tolerate at least 30 thermal cycles, between operating and room temperatures, over its design life. The unit

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manufactured cost, based upon a production volume of 1,000 units per year, should be estimated and justified.

Contact: Joseph Stoffa, 304-285-0285, Joseph.Stoffa@netl.doe.gov

27c. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Joseph Stoffa, 304-285-0285, Joseph.Stoffa@netl.doe.gov

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28. OIL AND GAS TECHNOLOGIES

Much of the resources of oil and natural gas in the U.S. cannot be recovered by conventional means, and advanced technologies are required for economical and environmentally compliant extraction. This topic seeks to develop technology that will lead to more efficient production of oil and natural gas by furthering the development of: (1) innovative tools or methods to reduce cost, increase recovery efficiency, and /or prevent/mitigate uncontrolled release of well fluids associated with either conventional or unconventional oil and natural gas reservoir development; and (2) innovative tools or methods to reduce exploration, processing, and field development costs – and/or improve recovery efficiency – associated with oil sands, tar sands, oil shale, and unconventional natural gas (tight gas sands, gas shales, coalbed methane).

Grant applications are sought in the following subtopics:

28a. Development of Petroleum and Natural Gas Fields
Grant applications are sought to develop innovative tools or methods to reduce cost and/or increase recovery efficiency associated with both conventional and unconventional oil and natural gas reservoir development. Approaches of interest include, but are not limited to, the development of (1) down-hole tools and methods that can decrease the time and cost associated with drilling hard formations, (2) drilling and stimulation methods that reduce the overall environmental footprint and/or minimize operational fluids handling (especially water use/reuse) associated with field development, (3) innovative methods to identify and produce bypassed oil in mature fields, (4) improved reservoir and fracture diagnostics to accurately identify spacing, direction, and extent of created fractures in horizontal wells, (5) methods for quick response spill containment and remediation, (6) field testing of new or improved subsurface zonal isolation methods, (7) improved techniques for remediating Underground Sources of Drinking Water (USDW) and watersheds affected by oil and gas development, or (8) safety, prevention, and

mitigation methods or techniques associated with uncontrolled release of well fluids in ultra-deepwater offshore areas.

Grant applications must include a succinct discussion of the potential technical and economic advantages of the proposed technology, as compared to existing state-of-the-art systems.

Contact: Albert Yost, 304-285-4479, albert.yost@netl.doe.gov

28b. Enhanced Recovery of Unconventional Resources

Grant applications are sought to develop innovative tools or methods to reduce geological and geophysical, environmental, processing, and field development costs – and/or improve recovery efficiency – associated with oil sands, tar sands, oil shale, and unconventional natural gas.

For unconventional oil resources, approaches of interest include methods to (1) reduce the technical environmental constraints, (2) improve in situ and above-ground processing barriers to resource development, and (3) improve overall oil recovery efficiency

For unconventional natural gas resources, approaches of interest include (1) new or improved smart reservoir and full-field development methods, (2) innovative methods to reduce drilling flat time (non-productive time), and (3) fit-for-purpose drilling rig design or retrofit systems for high-rate-of-penetration drilling. Proposed approaches must be cost-effective and environmentally friendly, and should result in high natural gas recovery efficiency across all producing formations.

Grant applications must include a succinct discussion of the potential technical and economic advantages of the proposed technology, as compared to existing state-of-the-art systems.

Contact: Albert Yost, 304-285-4479, albert.yost@netl.doe.gov

28c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Albert Yost, 304-285-4479, albert.yost@netl.doe.gov

REFERENCES

Subtopic a:

1. Applicants may review information about oil and natural gas programs at NETL'swebsite. (URL: http://www.netl.doe.gov/technologies/oil-gas/index.html)

2. Applicants may review the draft report entitled "Unconventional Fossil Energy: Domestic Resource Opportunities and Technology Applications" (URL: http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/UnconventionalFossilEnergy_Reportdraft4-23-10v2.pdf)

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Subtopic b:

1. Applicants may review information about oil and natural gas programs at NETL's website. (URL: http://www.netl.doe.gov/technologies/oil-gas/index.html)

2. Applicants may review the draft report entitled "Unconventional Fossil Energy: Domestic Resource Opportunities and Technology Applications" (URL: http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/UnconventionalFossilEnergy_Reportdraft4-23-10v2.pdf)

29. CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

Eighty-five percent of our nation's energy results from the burning of fossil fuels from vast reservoirs of coal, oil, and natural gas. These processes add carbon to the atmosphere, principally in the form of carbon dioxide (CO_2). It is important to understand the fate of this excess CO_2 in the global carbon cycle in order to assess contemporary terrestrial carbon sinks, the sensitivity of climate to atmospheric CO_2, and future potentials for sequestration of carbon in terrestrial systems. Therefore, improved measurement approaches are needed to quantify the change of CO_2 in atmospheric components of the global carbon cycle, and to understand processes and mechanisms of carbon sequestration of the terrestrial biosphere. There is also interest in innovative approaches for flux and concentration measurements of methane and other greenhouse gas constituents associated with terrestrial systems.

The "First State of the Carbon Cycle Report (SOCCR)" (Reference 1) provides rough estimates of terrestrial carbon sinks for North America. A DOE working paper on carbon sequestration science and technology (Reference 2) also describes research needs and technology requirements for sequestering carbon by terrestrial systems. Both documents call for advanced sensor technology and measurement approaches for detecting changes of atmospheric CO_2 properties and of carbon quantities of terrestrial systems (including biotic, microbial, and soil components). Such measurement technology would improve the quantification of CO_2 , as well as carbon stock and flux, in the major sinks identified by the SOCCR report (see Figure ES.1 therein).

Grant applications submitted to this topic should (1) demonstrate performance characteristics of proposed measurement systems, and (2) show a capability for deployment at field scales ranging from experimental plot size (meters to hectares of land, with comparable dimensions for marine systems) to nominal dimensions of ecosystems (hectares to square kilometers). Phase I projects must perform feasibility and/or field tests of proposed measurement systems to assure a high degree of reliability and robustness. Combinations of stationary remote and *in situ* approaches will be considered, and priority will be given to ideas/approaches for verifying biosphere carbon changes and for estimating carbon sequestration. Measurements using aircraft or balloon platforms must be explicitly linked to real-time ground-based measurements. Grant applications based on satellite remote sensing platforms are beyond the scope of this topic, and will be declined.

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Grant applications are sought in the following subtopics:

29a. Sensors and Techniques for Measuring Terrestrial Carbon Sinks and Sources

Measurement technology is required to quantify carbon sequestration by natural vegetation and ecosystems (i.e., carbon sinks) as well as CO_2 emissions to the atmosphere from natural or industrial sources. Grant applications are sought to develop sensors and unique measurement techniques (and associated system technology, if appropriate) to detect and quantify annual net carbon changes of terrestrial vegetation for large areas, or to measure and verify the magnitude of CO_2 emissions from various sources. Approaches of interest include the development of sensors to measure fluxes between the atmosphere and land-surface vegetation, new technology for accurate measurement of soil carbon content and change, and the development of miniaturized sensors to determine atmospheric CO_2 concentration.
For the measurement of CO_2 sinks, the sensor systems or new technology must be applicable for forests, grasslands, shrub lands, agricultural lands, and/or wetlands, and have the capability of producing spatially resolved aggregate estimates of terrestrial carbon changes to an accuracy of 10 to 25 $g/m^2/yr$ (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty.

For measuring emissions or atmospheric concentrations, the apparatus must be located at a point remote from the actual site of CO_2 release and provide accuracy estimates for CO_2 concentrations of approximately 0.3 ppm or less in dry air.

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

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

Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

29b. Novel Measurements of Carbon, CO2, and Trace Greenhouse Gas Constituents of Terrestrial and Atmospheric Media

Improved measurement technology is needed to better characterize processes involving carbon transformations of soil, vegetation, and associated ecosystem components and exchanges with the atmosphere. Particular areas of interest include high resolution measurements of soil carbon/organic matter – i.e., the carbon content of biological tissues in various components (e.g., phytomass, detritus) of terrestrial ecosystems; improved measurement technology for atmospheric CO_2 and its isotopes; and high accuracy and precision measurement of other trace greenhouse gases. Requests for specific grant applications are described in items (1) to (4) below:

(1) For determining the carbon content of biota and soil, grant applications are sought to develop and demonstrate measurement technology for estimating changes of carbon quantities and/or fluxes involving major components of ecosystems, with an accuracy on the order of 10 grams per square meter or less. Quantification of spatially resolved aggregate estimates of terrestrial carbon changes should have an accuracy of 10 to 25 $g/m^2/yr$ (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty.

(2) Grant applications are sought to design and demonstrate a new CO_2 analyzer that (a) can determine the mole fraction of CO_2 in dry ambient air to a relative precision of 1 part in 3000 or better, in one minute or less; (b) operates with small amounts of gas (30 cc/min or less) to minimize problems due to water vapor and to minimize consumption of reference gases, if employed; (c) is robust enough for unattended field deployment for periods of half a year or longer; (d) costs less than $5000 when manufactured in quantity; and (e) is not sensitive to motion.

(3) Grant applications are sought to develop lightweight sensors (approximately 100 grams) for measuring atmospheric CO_2. The sensors must be capable of measuring fluctuations of CO_2 in air of the order of plus or minus 1 ppm, in a background of 370 ppm. The devices must be suitable for launch on ballonsondes or similar platforms, and therefore must be insensitive to large changes in ambient temperature and pressure. The devices also must be able to operate on low power (e.g., 9v battery) and have a response time of less than 30 seconds.

(4) Grant applications are sought to develop new technology platforms that can be used to measure fluxes and/or concentrations of important trace greenhouse gas constituents, as well as the isotopes of carbon, methane, CO, and other trace species. Instrument designs should (a) place emphasis on determining the sources and sinks of carbon, CO, and trace species, and (b) ensure long-term and robust field deployment. Grant applications dealing with the remote measurement of vascular plant properties and processes will be considered, provided that they meet the requirements described below. o

In general, new technology for measuring terrestrial biota and soil must be accomplished by *in situ* and/or non-invasive means, across a range of temporal scales (from seconds to days) and spatial scales (from millimeters to kilometers), depending on the system properties being observed. The remote sensing of organic carbon is also of interest – the term "remote sensing" means that the observation method is physically separated from the object of interest. All instruments must be portable and deployable in remote locations, and must not adversely impact the site of deployment. Two other approaches are also of interest: (1) the development of unique surface-based observations that are used for the calibration/interpretation of other remotely derived data; and (2) potential applications of CO_2 sensors via ballonsonde – however, remote sensing data acquisition by airborne or satellite platforms will not be considered.

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Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

29c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

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30. ENHANCED AVAILABILITY OF CLIMATE MODEL OUTPUT

Much of the nearly $2 billion annual research budget for the U.S. Global Change Research Program supports research from the Department of Energy, National Aeronautics and Space

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Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and National Science Foundation (NSF) Studies supported by this research budget, include modeling and simulation of long-term climate change. Model output resulting from climate change projections is a valuable resource and the DOE has played a crucial role in providing such datasets to the research community. For example, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php) makes available a subset of multi-model output from the Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Report to researchers for non-commercial purposes only. However, other users, particularly non-researchers that intend to use the data for commercial purposes, have been requesting access to the multi-model output. As the temporal and spatial resolution of models increase, vast amount of climate model output are generated; access and analysis of such data by non-researchers is a daunting challenge.

Grant applications are sought in the following subtopic:

30a. Accessibility of Climate Model Data to Non-Researchers
The purpose of this subtopic is to broaden the usage of federally-funded, long-term climate change simulations of high-end climate models, such as the Community Climate System Model, the NOAA Geophysical Fluid Dynamics Laboratory model, and the NASA Goddard Institute for Space Studies model. Therefore, grant applications are sought to develop technology for making the output of these models more accessible to a variety of users. Approaches of interest include the development of (1) preferred data formats for users of climate model output in particular applications (e.g., agriculture, water resources, energy); (2) methods for converting the data from existing data formats to formats required by users in the application communities; and (3) improved software frameworks and prototypes for data access by distinct application communities. Applicants are expected to document lessons learned in the experience of providing climate model output data to the non-research community.

Contact: Renu Joseph, 301-903-9237, Renu.Joseph@science.doe.gov

30b. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Renu Joseph, 301-903-9237, Renu.Joseph@science.doe.gov

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2. DOE’s Atmospheric Radiation Measurement (ARM) Program provides improved scientific understanding of the fundamental physics related to interactions between clouds and radiative feedback processes in the atmosphere. (URL: http://www.arm.gov/)

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3. DOE's AmeriFlux provides continuous observations of ecosystem level exchanges of CO_2, water, energy and momentum spanning diurnal, synoptic, seasonal, and interannual time scales. (URL: http://public.ornl.gov/ameriflux/)

31. ATMOSPHERIC MEASUREMENT TECHNOLOGY

World-wide energy production is modifying the chemical composition of the atmosphere. Such modifications are linked not only with environmental degradation and human health problems but also with changes in the most sensitive parts of the physical climate system – namely, clouds and aerosols. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change examined the effect of changes in clouds and aerosols on the Earth's energy balance. It was determined that innovative measurement technologies are needed to provide both input and comparison data for models used to assess the energetic impacts of clouds and aerosols. These technologies will require high accuracy and time stability, in order to support a strategy of sustainable and pollution-free energy development for the future.

Grant applications that respond to this topic must propose Phase I bench tests of critical technologies. ("Critical technologies" refers to components, materials, equipment, or processes that overcome significant limitations to current capabilities.) In addition, grant applications should (1) describe the purpose and benefits of any proposed teaming arrangements with government laboratories or universities, and (2) 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 proposing only computer modeling without physical testing will be considered non-responsive.

Grant applications are sought in the following subtopics:

31a. Tethered Balloon Systems for Arctic Measurements in the Near-Surface Atmosphere

Long-term measurements of the microphysical and radiative properties of Polar clouds are needed to reduce uncertainties in global climate models (GCM's). Due to reduced duration, crew fatigue and cost, conventional research aircraft are incapable of making these measurements. Satellite retrievals provide a long-term and comprehensive dataset, but the retrieval algorithms contain significant uncertainties that need improvements based on in-situ measurements. Unmanned aerial systems (UAS's), in particular tethered balloon systems (TBS) and small, unmanned aerial vehicles (UAV's) are platforms capable of making long-duration, cost-effective, in situ cloud measurements (Holland et al. 2001, Stamnes and Storvold 1999, Lawson et al. 2010, Sikand et al. 2010). In addition to making long-term, cost-effective in-situ cloud microphysical and radiative measurements, a TBS makes vertical profiles of clouds from approximately 2 km aloft to the surface. Unlike aircraft, the proposed instrument should cover the full vertical extent of most boundary-layer Arctic clouds. For example, Lawson et al. (2001) shows that 8 of the 11 SHEBA/FIRE.ACE boundary layer clouds had tops within 2 km of the surface.

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Depending on horizontal wind speed, a TBS profile is nearly vertical relative to a moving cloud, whereas an aircraft makes either slant or spiral profiles, which mix regions of clouds over horizontal scales of several kilometers. Due to the relatively slow (~ 10 m s^{-1}) aspiration speed, TBS microphysical measurements from Cloud Particle Imager and forward scattering instruments will not be subjected to ice crystal shattering on probe inlets, which has been a problem with aircraft measurements (e.g., Field et al. 2006).

The ability of a TBS to make long-duration microphysical and radiative measurements in Arctic and Antarctic clouds has been demonstrated in pilot projects (Lawson et al. 2010; Sikand et al. 2010). However, development of miniature microphysical and radiative sensors capable of operating on TBS and small UAV's is in its embryonic stage. Small, lightweight instruments (i.e., order 1 – 2 kg) are required to make measurements of:

- Size, shape, number concentration and mass content of cloud water drops and ice particles,
- size and concentration of aerosols, ice forming nuclei and cloud condensation nuclei,
- cloud radiative properties at solar and near infrared wavelengths,
- volumetric measurements of cloud extinction.

Phase I research should include detailed design of sensors coupled with laboratory tests and evaluation of critical subsystems. The field deployment shall demonstrate the capabilities of the new instrumentation in clouds and show how the measurements can be used to improve parameterisations used in GCM's.

Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

31b. Oxygen-Band Spectrometer

Both simulations and short-field deployments using the oxygen "A" and "gamma" bands have demonstrated that the path-length distribution of solar photons, and especially the moments of this distribution, respond strongly to variations in the opacity and spatial distribution of clouds in both the vertical and horizontal directions. As a consequence of this relationship, the moments of the path-length distribution can be used to (1) infer cloud properties, and (2) diagnose the process of absorption of shortwave radiation by greenhouse gases in the presence of complex cloudiness. In order to infer the most meaningful moments (mean, variance, etc.) of the path-length distribution of solar photons – from the top of the atmosphere to the sensor – ground-based differential absorption spectrometry of molecular oxygen could be used, provided that the resolution is sufficiently high.

Therefore, grant applications are sought to develop robust, field-worthy oxygen-band spectrometers capable of accurately measuring the first three moments of the photon path-length distribution. For an A-band instrument, the following specifications apply:

(1) The wavenumber resolution should be 2-4 cm^{-1}.
(2) The wavelength stability should be 1/20 FWHM or better.

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(3) At a given resolution, the number of independent pieces of path-length information that can be accurately inferred depends strongly on the out-of-band rejection of the slit function. This out-of-band rejection should not exceed $3x10^{-4}$.
(4) Instrument operation should provide a zenith-pointing narrow field-of-view (a few degrees), with an option for a hemispherical field-of-view as well.
(5) The signal-to-noise ratio should exceed 100:1 at the darkest wavelength, with integration times on the order of a minute.
Designs based on other solar spectral bands of oxygen are also of interest, provided that they perform as well in terms of information content and accuracy of the photon path-length. For all spectral bands, a fieldable instrument will have to operate reliably and autonomously under any weather condition.

These spectrometers would be deployed by the DOE's Atmospheric Radiation Measurement (ARM) Program in support of its observational climate science mission. Thus, applicants will be expected to work closely with the ARM Program to refine the requirements listed above and to arrange for field tests of the instrument at ARM sites. In particular, applicants will be expected to coordinate with the ARM Science Team's A-band Focus Group, to ensure that the science requirements are met.

Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

31c. Measurements of the Chemical Composition of Atmospheric Aerosols
Improved measurement methods are needed for the real-time characterization of the bulk and the size-resolved chemical composition of ambient aerosols, particularly carbonaceous aerosols. Such improved measurements would be used to facilitate the identification of the origin of aerosols, (i.e., primary versus secondary and fossil fuel versus biogenic). Also, these measurements could help elucidate how the particles of an aerosol are processed in the atmosphere by chemical reactions and by clouds, and how their hygroscopic properties change as they age. This information is important because relatively little is known about organic and absorbing particles, which are abundant in many locations in the atmosphere. In particular, there is a need for instruments suitable for real-time measurements of the composition of these particles at the molecular level. Although recent advances have led to the development of new instruments, such as particle mass spectrometers and single particle analyzers, these instruments have important limitations in their ability to quantify black carbon vs. organic carbon, provide speciation of refractory and volatile organic compounds, and calibrate both organic and inorganic components. Furthermore, instruments that otherwise would be suitable for ground-based operation often have limitations (size, weight, power, stability, etc.) that restrict their application for *in situ* measurements, where critical atmospheric processes actually occur (e.g., in or near clouds).

In order to better understand the chemical composition of atmospheric aerosols, grant applications are sought to develop improved instruments, or entirely new measurement methods, that provide: (1) speciation of individual organics, including those containing oxygen, nitrogen, and sulfur; (2) identification of elemental carbon and other carbonaceous material, so that the makeup of the absorbing fraction is known; (3) identification of source markers, such as isotopic abundances in aerosols; and (4) the ability to probe the chemical composition of aerosol surfaces.

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Proposed approaches that can measure aerosol chemical composition from airborne platforms would be of particular interest.

In order to address the deficiencies associated with current techniques, proposed approaches should seek to provide: (1) quantifiable results over a wide range of compounds, which is a deficiency of laser ablation aerosol mass spectrometer methods; (2) measurements over a range of volatility so that dust, carbon, and salt are detectable, which is a deficiency of thermal decomposition aerosol mass spectrometers; and (3) measurements with high time resolution, which is a deficiency of filter techniques.

Contact: Ashley Williamson, 301-903-3120, ashley.williamson@science.doe.gov

31d. Measurements of the Chemical Composition of Atmospheric Aerosol Precursors

In order to better understand the evolution of aerosols in the open air, grant applications are sought to develop instruments that can make fast measurements of gas phase organics or other substances that might either condense or dissolve into aerosols or cloud droplets. Of special interest are volatile organic compounds (VOC) and intermediate volatility organic compounds (IVOC). Although VOCs and IVOCs partition primarily into the gas phase, they may react with gaseous oxidants or with existing aerosol particles and droplets to form a secondary organic aerosol (SOA) mass. Current methods for predicting SOA production rates, based only on precursor organic compounds that have been quantified (both VOCs and oxygenates), underestimate SOA production by factors of 3 or more. One problem is that many gaseous organic compounds are not detected by commonly-used techniques, such as gas chromatographic or chemical ionization-mass spectrometric methods.

Grant applications also are sought to develop instruments to determine the total amount of carbon in these organic compounds. The data provided by these instruments would allow scientific insights to be gained regarding the reason for the underestimation of SOA production. (That is, is the underestimation due to key precursors that are not measured? Or, is it due to the use of extrapolations – from laboratory kinetic and equilibrium data – that were not appropriate for ambient conditions?)

Finally, grant applications are sought to develop improved measurements of inorganic aerosol precursors. Examples of compounds of interest (with desirable detection limits and response rates listed in parenthesis) include gaseous HNO_3 (0.1 ppbv, 1 Hz), O_3 (2-3 ppbv, 10 Hz), and SO_2 (5 pptv, 1 Hz).

In addition to the free-air measurements described above, grant applications are sought to develop instruments or instrument systems for measuring aerosol precursors in cloud droplets. Such systems must address (1) methods for the efficient sampling of droplets; and (2) a mechanism for transferring the sample to the appropriate analytical instrumentation, in which the organic or inorganic target analytes are measured. Of particular interest are systems that can separate or discriminate between interstitial compounds and compounds that occur dissolved or suspended within cloud droplets.

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Proposed instruments that are suitable for sampling from airborne platforms (that is, with reduced weight and power requirements, high sensitivity, and fast response time) would be of particular interest.

Contact: Ashley Williamson, 301-903-3120, ashley.williamson@science.doe.gov

31e. Aerosol Size Distributions

Knowledge of particle size distribution is essential for describing both direct and indirect radiative forcing by aerosols. However, current techniques for determining these distributions are often ambiguous because of the assumption that the particles are spherical. In particular, the optical techniques most often used in the 0.5-10 µm size range have inherent problems. Therefore, grant applications are sought for techniques, which are not based on optical properties, to determine the size distribution of ambient aerosols in the 0.1 - 10 µm size range. Proposed approaches must address the influence of relative humidity and must be integrated with the simultaneous measurement of such properties as mass concentration, area (extinction), and particle number.

Grant applications also are sought to develop fast (~ 1 sec) and lightweight (suitable for sampling from airborne platforms) instruments for (1) particle size spectrum measurements in the 10- 600 nm size range, and (2) for cloud droplet/drizzle measurements (10–1000 µm size range). Related airborne measurements of great interest are (3) a fast spectrometer for measurement of cloud condensation nuclei number concentrations over supersaturation ranges of the order 0.02% – 1% and (4) a spectrometer/counter for ice nuclei (IN) number concentrations over effective local temperatures down to -38 °C.

Contact: Ashley Williamson, 301-903-3120, ashley.williamson@science.doe.gov

31f. Aerosol Scattering and Absorption (in situ)

The aerosol absorption coefficient, together with the aerosol scattering coefficient, determines the single-scattering albedo. This key aerosol property, along with the factors that contribute to it, are critical for determining heating rates and climate forcing by aerosols. Therefore, grant applications are sought to develop reliable instruments for the *in situ* measurement of the single-scattering albedo for particles containing black and organic carbon, dust, and minerals. The measurements must cover the solar wavelengths (UV, visible, and near infrared), must not alter aerosol properties, and must address the influence of relative humidity.

Contact: Ashley Williamson, 301-903-3120, ashley.williamson@science.doe.gov

31g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Rick Petty, 301-903-5548, rick.petty@science.doe.gov

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32. TECHNOLOGIES FOR SUBSURFACE CHARACTERIZATION AND MONITORING

New measurement and monitoring tools for interrogating physical, chemical, and biological processes in subsurface environments are important elements of Department of Energy (DOE) research efforts to support the assessment of remediation performance and DOE site stewardship. The purpose of these research efforts is to determine the fate and transport of contaminants generated from past weapons production activities, assess and control processes to remediate contaminants, and provide for the long-term monitoring of sites.

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Grant applications submitted to this topic must describe why and how proposed *in situ* fieldable technologies will substantially improve the state-of-the-art, include bench and/or field tests to demonstrate the technology, and clearly state the projected dates for likely operational deployment. New or advanced technologies, which can be demonstrated to operate under field conditions with mixed/multiple contaminants and can be deployed in 2-3 years, will receive selection priority. Claims of relevance to DOE sites, or of commercial potential for proposed technologies, must be supported by endorsements from relevant site managers, market analyses, or the identification of commercial spin-offs. Grant applications that propose incremental improvements to existing technologies are not of interest and will be declined.

For the following subtopics, collaboration with government laboratories or universities, either during or after the SBIR/STTR project, may speed the development and field evaluation of the measurement or monitoring technology. In addition, some of these organizations operate user facilities that may be of value to proposed projects. These facilities include:
Integrated Field Research Challenge (IFRC) research sites in Oak Ridge, TN (http://www.esd.ornl.gov/orifrc/index.html); Old Rifle, CO (http://ifcrifle.pnl.gov/); and Hanford, WA (http://ifchanford.pnl.gov/). At IFRC research sites, scientists can conduct field-scale research and obtain DOE-relevant samples of soils, sediments, and ground waters for laboratory research.

The Environmental Molecular Science Laboratory (EMSL) at the Pacific Northwest National Laboratory (http://www.emsl.pnl.gov). EMSL is a national scientific user facility with state-of-the-art instrumentation in environmental spectroscopy, high field magnetic resonance, high performance mass spectroscopy, high resolution electron microscopy, x-ray diffraction, and high performance computing.
Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements.

Grant applications are sought in the following subtopics:

32a. Mapping and Monitoring Hydrogeologic Processes in the Shallow Subsurface
While subsurface characterization methods are improving and yielding higher-resolution data, they are still not routinely used to describe flow and transport processes or to guide remediation activities. Grant applications are sought to develop high-resolution geophysical, geochemical, or hydrogeological methods to: (1) characterize subsurface properties that control the transport and dispersion of contaminants in groundwater and the unsaturated zone, or (2) monitor dynamic processes such as fluid flow, contaminant transport, and geochemical and microbial activity in the subsurface. Approaches of interest include the development of:

- integrated approaches where geophysical data are combined with other types of data (e.g., core analyses, well logs, hydrogeologic and geochemical information) to better constrain and evaluate flow and transport models;
- improved tools and methods for hydrogeologic characterization using cone-penetrometers and conventional well logging systems;

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- innovative advances of temperature sensing technologies and approaches for hydrological characterization and monitoring from subsurface, surface, or airborne platforms; and
- improved methods for the long-term monitoring (for one year, ten year, and one hundred year time frames) of contaminated sites, using integrated sensor networks.

Contact: David Lesmes, 301-903-2977, david.lesmes@science.doe.gov

32b. Real-Time, In Situ Measurements of Geochemical, Biogeochemical and Microbial Processes in the Subsurface

Sensitive, accurate, and real-time monitoring of geochemical, biogeochemical, and microbial conditions are needed in subsurface environments, including groundwater, sediments, and biofilms. In particular, highly selective, sensitive, and rugged *in situ* devices are needed for low-cost field deployment in remote locations, in order to enhance our ability to monitor processes at finer levels of resolution and over broader areas. Therefore, grant applications are sought to develop innovative sensors and systems to detect and monitor geochemical and biogeochemical processes that control the chemical speciation or transport of metals and radionuclides in the subsurface. Only the following radionuclides and metals are of interest: technetium, chromium, strontium-90, mercury, uranium, iodine-129, plutonium, americium, cesium-137, and cobalt. The ability to distinguish between the relevant oxidation states of these elements and their chemical species is of particular concern. In addition, the microbes and metabolic processes of interest are limited to those that may be involved in controlling the subsurface fate, transport, and remediation of these elements. Grant applications that address other contaminants will be declined. Grant applications must provide convincing documentation (experimental data, calculations, etc.) to show that the sensing method is both highly sensitive (i.e., low detection limit), precise, and highly selective to the target analyte, microbe, or microbial association (i.e., free of anticipated physical/chemical/biological interferences). Approaches that leave significant doubt regarding sensor functionality in realistic multi-component samples and realistic field conditions will not be considered.

Grant applications also are sought to develop integrated sensing systems for autonomous or unattended applications of the above measurement needs. The integrated system should include all of the components necessary for a complete sensor package (such as micro-machined pumps, valves, micro-sensors, solar power cells, etc.) for field applications in the subsurface. Approaches of interest include: (1) fiber optic, solid-state, chemical, or silicon micro-machined sensors; and (2) biosensors (devices employing biological molecules or systems in the sensing elements) that can be used in the field – biosensor systems may incorporate, but are not limited to, whole cell biosensors (i.e., chemiluminescent or bioluminescent systems), enzyme or immunology-linked detection systems (e.g., enzyme-linked immunosensors incorporating colorimetric or fluorescent portable detectors), lipid characterization systems, or DNA/RNA probe technology with amplification and hybridization. Substantial progress has been made in fiber optics and chemical sensing technology in the last decade; therefore, grant applications that propose minor adaptations of readily available materials/hardware, and/or cannot demonstrate substantial improvements over the current state-of-the-art, are not of interest and will be declined.

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Contact: David Lesmes, 301-903-2977, david.lesmes@science.doe.gov

32c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: David Lesmes, 301-903-2977, david.lesmes@science.doe.gov

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33. IMAGING AND RADIOCHEMISTRY

The Radiochemistry and Imaging Instrumentation Program advances the DOE mission by supporting radiochemistry and radionuclide imaging research into the real-time visualization of dynamic biological processes in energy and environmentally-relevant contexts. In particular, the program supports research that could be beneficial for metabolic imaging in living systems, including plants and microbial-communities that are relevant to biofuel production and bioremediation, and that are transferable for use in nuclear medicine research and in applications by NIH and industry.

Grant applications are sought in the following subtopics:

33a. Radiochemistry and Radiotracers for Imaging

Grant applications are sought in three new areas of radiochemistry: (1) development of new chemical reactions to overcome the synthetic constraints of working with radioisotopes at high specific activity, in order to provide more generally applicable radiolabeling techniques; (2) construction of nanoparticle platforms, for incorporation of one or more imaging agents and targeting moieties; and (3) new automation technologies, in order to provide readily adaptable, versatile purification techniques (e.g., microfluidics and kits) that can serve as transformational tools for radiotracer synthesis. Proposed approaches that directly advance the DOE mission will be given preference. However, approaches that do not involve radionuclide imaging capability are not of interest and will be declined.

Contact: Prem Srivastava, 301-903-4071, prem.srivastava@science.doe.gov

33b. Advanced Imaging Technologies for Plant and Microbial System

Grant applications are sought for new, sensitive, high-resolution instrumentation for radionuclide imaging of plants and microbial systems. The instrumentation should advance the application of radiotracer methodologies for imaging molecular biological functions in living systems, including cell communication and gene expression *in vivo*.

Areas of interest include the development of:

New detector materials and detector arrays for both positron emission and single photon emission computed tomography for studying biologic processes in plants and microbial communities. The application of radionuclide imaging to plants and microbial communities may

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require exploration of new scanner geometries and size scales to match the diversity of such new uses.

Software for rapid image data processing and image reconstruction at the highest possible special and temporal resolutions

Hybrid imaging systems that combine radionuclide imaging data in novel ways with the high spatial resolution achievable with CT, MRI, optical, or ultrasound imaging

Methods of integrating *in vitro* and *in vivo* imaging instrumentation technologies for real-time radionuclide-based molecular imaging of biological function.

Only instrumentation development applications that focus on the imaging of plants and microbial system will be accepted.

Contact: Dean Cole, 301-903-3268, dean.cole@science.doe.gov

33c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Dean Cole, 301-903-3268, dean.cole@science.doe.gov

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2. "Supplementary Information," at Website for DOE Office of Science, Radiochemistry and Instrumentation Research Funding Opportunity Announcement Notice DE PS02-09ER09-18 (Available at http://science.doe.gov/grants/pdf/DE-FOA-0000265.pdf, Scroll down page to text under "Supplementary Information.")

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34. GENOMIC SCIENCE AND RELATED BIOTECHNOLOGIES

The Department of Energy (DOE) supports research to acquire a fundamental understanding of biological and environmental processes. This includes the display of genomes as DNA sequences; the functional characterization of gene products, especially from DOE-relevant plants and microbes; structural biology user stations at synchrotron sources and neutron sources; computational genomics; and the development of integrated information systems. This topic is focused on the goals of the Genomic Science program: namely, to develop a detailed understanding of the molecular machines of energy relevant plants, relevant microbes and their networking in living cells and microbial communities. Plants and microbes with capabilities that can further several DOE programmatic missions are being used as the current subjects for these studies. This information will be progressively gathered and cross correlated in a developing System Biology Knowledge Base (1). The information and capabilities thus gained is enabling both the public and private sectors to: apply genome knowledge to the bio-production of energy, promote environmental applications such as bioremediation and carbon sequestration, promote cleaner industrial processes, and enable increasingly effective computational models of the microbial cell. For some of the subtopics below, capabilities already exist in a few laboratories, but commercial involvement will be needed before the technology can be exported to the broader research community.

Grant applications are sought in the following subtopics:

34a. Systems for Assembly of Metagenomic Sequence Data
With the advent of faster and cheaper genomic sequencing machines the biology community will see an order of magnitude increase in sequencing DNA/RNA to infer microbial, plant and community information. It remains a challenge to assemble the sequencing data from large microbial environmental and community samples. Applications are being sought to develop new algorithms for the assembly of large quantities of sequencing data from short read platforms. Algorithms that are developed for cloud or GPU/CPU hybrid architectures are of particular interest.

Contact: Marvin Stodolsky, 301-903-4475, marvin.stodolsky@science.doe.gov

34b. Software Tools for the GTL Systems Biology Knowledgebase (SBK)
The SBK is in a stage of active development and could benefit from complementing software tools. These can include but are not limited to tools for:

- Development of Laboratory Information Management Systems (LIMS) to integrate together different types of experimental biological data such as proteomics, transcriptomics, flux and network data with genomic data.
- development of algorithms (e.g. machine learning) to construct dynamical networks that predict changes or influences of environmental factors on an organisms phenotype;
- automotive software to extract biologically relevant information from different databases, such as microarray, proteomic, metabolomic data;
- development of web-to-web services for bioinformatic tools.

Contact: Marvin Stodolsky, 301-903-4475, marvin.stodolsky@science.doe.gov

34c. Dueterated Macromolecule Resources
The cultivation of source organisms on dueterated media is necessary for the optimal application of neutron imaging or scattering techniques to biological materials. Although cogent growth resources are available for such long-used hosts as *Escherichia coli*, suitable standardized media and techniques for the cultivation of other bacteria of interest (e.g., the yeast *Saccharomyces* and other eukaryotes) are either not yet robust or adequately reliable. Therefore, grant applications are sought to develop improved cultivation resources for such hosts. The dueterated target products of interest are components of lignocellulosic biomass and sterols.

Contact: Marvin Stodolsky, 301-903-4475, marvin.stodolsky@science.doe.gov

34d. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Marvin Stodolsky, 301-903-4475, marvin.stodolsky@science.doe.gov

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35. SMART FACILITIES AND GREEN NETWORKS

DOE operates numerous scientific facilities ranging from particle colliders, to supercomputers, to national backbone networks. While these instruments and facilities can enable the discovery of new scientific knowledge, they consume large amounts of power to operate effectively. Improving the efficiency of these instruments and facilities can greatly reduce their energy needs without impacting their science mission.

These power consumption and other "green" issues are fast becoming the information technology (IT) industry's biggest challenge. Power consumption of HPC and networking components had never been a real issue for most users - until it started to reach levels at which it impacted cooling, noise and reliability. In the next ten years, it is estimated that efficient energy saving computing and networking will cut greenhouse gas emissions in an amount equal to removing more than 11 million cars from the road or shutting down 20 500-megawatt coal-fired power plants. Accomplishing this goal will require retrofitting existing hardware and related cooling systems with energy-aware sensors to minimize power consumption and ensuring that new systems are energy efficient.

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This topic solicits proposal that could directly reduce the energy needs of these instruments or improve the collection of data needed to make energy management decisions.

Grant applications are sought in the following subtopics:

35a. Standardized Energy Measurement Interfaces, Integration with Facility Infrastructure, and Energy-Aware Algorithms

The understanding of power consumption from individual components of High Performance Computing (HPC) systems and datacenters is extraordinarily poor. Moreover, the power consumed by the hardware, the software that runs on the hardware, and the power and cooling infrastructure of the building in which the HPC system resides are all closely coupled. A power-efficient computing solution is needed to integrate these components through a standardized interface for exchanging energy consumption data (sensors) and enabling the fine-grained control of system elements (actuators). This subtopic addresses energy measurement interfaces, integration of building and HPC systems, and algorithms to improve energy efficiency:
No standard now exists for collecting energy consumption information at either the node level or the component level within HPC systems. The availability of a fine-grained, standardized power measurement interface would enable development of power-aware software that uses performance metrics to make decisions to optimize power consumption, both at the system and micro-architectural level. Therefore, grant applications are sought to develop standardized information-collection interfaces capable of integrating fine-grained power consumption data from HPC nodes to (1) provide a global view of system energy consumption, and (2) enable systems to autonomically react to the current state of the environment.

It also would be useful to integrate the information flow from HPC energy monitoring systems with HVAC systems, in order to provide real-time feedback and optimize the cooling and power management systems. Therefore, grant applications are sought to develop building infrastructure control systems that can monitor the information collected by standard energy-counter interfaces and optimize airflow and power distribution to achieve gains in the overall energy efficiency of the facility. One possible approach is to collect the instrumentation data and the facility's HVAC information into a formalized information repository that will enable both hardware and software components to react intelligently to environmental conditions. Such a repository could broaden the understanding of datacenter power consumption, assist in the planning of future facilities and HPC systems hardware, and make the information transparently available to third parties via open standards.

Application performance data can be used to make the best use of power-saving features when waiting for constrained resources such as the interconnection network or memory. Power-aware algorithms can provide detailed hints to hardware about its resource requirements. Currently an open research area, one important aspect of this effort is the correlation of high level application behavioral metrics to power consumption. Therefore grant applications are sought to develop computer algorithms and resource scheduling systems that are capable of using information from the energy monitoring system to improve energy efficiency without sacrificing computational performance.

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Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

35b. Energy-Efficient Networking Technologies

As the temperature of the Earth's surface gradually increases, the need to understand and reduce the energy consumption of computing and communication infrastructure in home, enterprise and data center environments has become an area of increasing importance in network engineering and operations. The power consumption of carrier-grade network devices (i.e., Ethernet switches, routers, enterprise servers, ROADM) and home networking equipments (i.e., wireless routers, Ethernet switches) that operate continuously have major impacts on, and contribute to, the global IT carbon foot print. Grant applications are sought in the development of technologies that can be used to enable energy-efficient networking. The technical areas of interest include but are not limited to a) smart sensor systems to enabled efficient power usage in GigaPops, large data centers, supercomputing facilities, etc., 2) smart controllers and sensors networks for minimizing the power consumption of networking devices, 3) cost-effective technology for power distribution for electronic device in homes such as Power Over Ethernet (PoE) technologies, 4) smart power supplies for home computing and network equipments, and 5) Smart agents and devices for controlling and managing power grids.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

35c. Low Power Embedded Networking Sub-Systems

Embedded networked sensor (ENS) systems are now used for many critical applications including personal communication systems (i.e., Wireless cell phones, GPS devices). Environmental monitoring applications now require complex sensors and control systems and the computational requirements of these devices have also increased. So too have the peak computing, network bandwidth, and memory requirements increased as sensors collect more and more data. These new demands have inevitably lead to high peak power consumption, which in turn have limited the time which these devices can operate before being recharged. Additionally end-user expects a feature-rich product, typically powered by a small battery and they demand a compact form factor. Finally, the scope of an embedded product is now expanding to include power-hogging devices such as wireless LAN (WLAN) radios, fast hard disc drives, and larger LCDs displayes.

Grant applications are sought to develop energy-aware embedded network subsystems, energy-aware routing subsystems, micro-power sensors, light-weight embedded operating systems, especially Linux or Unix derivatives, low-power interconnection networks and routers (on-chip networks), that can reliably support advanced sensing tasks (such as feedback controlled detection of metal composition in industrial environments, or rapid field analysis of ambient micro-organisms). These sensor systems should include a computational methodology for initiating the analysis, and storing and displaying the results, while consuming minimal power and being compact and portable.

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Contact Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

35d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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36. CLOUD COMPUTING

Cloud computing environments do not come preconfigured for High Performance Computing (HPC) applications. Users of such services must, in effect, build their own HPC software environment in order to make such services useful. This effort includes developing and/or configuring compilers, numerical libraries, parallel file systems, and data management tools, all of which are necessary for a computing environment that is typically provided by an HPC site.

Grant applications are sought in the following subtopic:

36a. Turn-Key HPC in the Cloud

An HPC environment, pre-packaged as a turnkey solution for cloud services, would enable DOE users, academic institutions, and even private companies to purchase access to cloud computing services in a pay-as-you-compute manner. Hence, grant applications are sought for innovative pay-as-you-go cloud HPC environments. Approaches of interest include, but are not limited to, the development and sale of pre-configured compute nodes for (1) existing systems, (2) software packages that run on the user's system and virtualize access to remote and distributed cloud computing resources, and (3) full-fledged web portals that implement a Software-as-a-Service (SAS) model that virtualizes access to back-end cloud services.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

36b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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37. DATA MANAGEMENT AND STORAGE

DOE operates several petaflop scale computing facilities that support multiple open science communities. These supercomputers are capable of generating terabytes of data in a single computation. As these supercomputers scale and generate petabyte and exabyte size data sets, new hardware and software for effectively managing this massive amount of data will be needed.

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This notice solicits novel proposals that address the significant challenges, both in terms of storing data at various levels of the memory hierarchy and in quickly retrieving data of interest, of these data management and storage issues.

37a. Green Storage for HPC with Solid State Disk Technologies: From Caching to Metadata Servers

Most solid-state storage devices (SSDs) use non-volatile flash memory, which is made from silicon chips, instead of using spinning metal platters (as in hard disk drives) or streaming tape. By providing random access directly to data, the delays inherent in electro-mechanical drives are eliminated. The common consumer versions, known as flash drives, are compact and fairly rugged. Advantages attributed to SSDs include higher data transfer rates, smaller storage footprint, lower power and cooling requirements, faster I/O response times (up to 1000 times faster than mechanical drives), improved I/O operations per second (IOPS), and less wasted capacity.

Furthermore, upcoming processor chip designs from Intel and AMD will include SSD/FLASH controllers built on-board the CPU chip, in order to improve integration for laptop and embedded applications. Such technology is likely to enable a localized checkpoint-restart capability to mitigate increased transient failure rates on future ultra-scale computing systems. This increased level of hardware integration makes it clear that x86 server nodes, which incorporate SSD directly onto the node, are on the horizon.

In view of these developments, the DOE seeks to improve its understanding of the implications of SSDs for large-scale, tightly-coupled systems in High Performance Computing (HPC) environments. Therefore, grant applications are sought to further develop SSD technology as a cost-effective and productive storage solution for future HPC systems, including, but not limited to:

1) **Categorization of SSD failure modes** - The rate of deployment of SSDs in HPC environments will be artificially slowed until a better understanding of the failure modes of this new class of storage is achieved. Proposed approaches should categorize the type of failure (wire bond, cell wear-out, or other failure) and determine how the failures would be detected and/or repaired in a composite device fielded in an HPC environment.

2) **Use of SSD for node-local storage, for faster (localized) checkpoint/restart (CPR)** - If transient failures cause nodes to die, then SSD could be a viable approach for fault-resilience. However, for nodes subjected to hard-failures, the use of SSD could produce an even higher node failure rate, due to the inherent failure characteristics of the SSD; in this case, the SSD approach would not be viable for CPR. Approaches of interest should collect and analyze data on the known failure modes of existing SSD components vis-a-vis node failure modes, in order to determine if SSD presents an effective alternative to the checkpoint/restart of a shared file system.

3) **Use of SSD for scalable out-of-core applications** - Although node-local disk systems have been used to support some applications that use out-of-core algorithms (such as some components of NWChem), the failure rates of spinning disks have rendered this practice

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unfeasible. Rather, central file systems are used to support these out-of-core applications, greatly affecting their scalability. Approaches are sought to determine whether local SSD might be reliable enough to enable a scalable approach to out-of-core processing.

4) **Use of SSD for metadata servers -** Metadata servers subject disk subsystems to many very small transactions, a feature that is very difficult to support with existing mechanical/spinning-disk based systems. SSDs might respond better to the random-access patterns required for metadata servers, but may not perform as well for write functions. Approaches of interest should analyze the data access patterns of a typical HPC Lustre metadata server and, using an SSD performance model, determine how well an SSD-based system would respond to a metadata server load.

5) **Use of SSD for accelerated caching for the front-end of large-scale disk arrays** – The use of SSDs in caching for large-scale disk arrays is an emerging technology that is not well understood. Approaches are sought to determine of both its performance potential when subjected to real workloads and its fault resilience.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

37b. Data Management Tools for Automatically Generating I/O Libraries

Database-like, self-describing, portable binary file formats, such as Network Command Data Form (NetCDF) and Hierarchical Data Format (HDF), greatly enhance scientific I/O systems by raising the level of abstraction for data storage to very high-level semantics (of data schemas and relationships between data objects stored) rather than low-level details of the location of each byte of the data stored in the file. However, both NetCDF and HDF5 still rely on very complex APIs to describe the data schema, and many performance pitfalls can arise if the APIs are not used in an optimal manner. Consequently, application developers must invest considerable effort in creating their own “shim” I/O APIs that are specific to their applications, in order to hide the complexity of the general-purpose APIs of NetCDF and HDF5.

Grant applications are sought to develop software tools that not only would enable rapid prototyping of high-level data schemas but also would automatically generate a high-level API for presentation to application developers, thereby hiding the complexity of the low-level NetCDF and HDF5 APIs for managing the file format. Such tools also might use auto-tuning techniques to find the best performing implementation of an I/O method.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

37c. Integration of Scientific File Representations with Object Database Management Systems

Scientific file formats like Network Command Data Form (NetCDF) and Hierarchical Data Format (HDF5) have capabilities that closely match those of commercial Object Database Management Systems (ODBMS); yet, commercial ODBMSs provide much more sophisticated data management tools than are available to users of NetCDF and HDF5. Unfortunately, ODBMSs are not designed to accommodate parallel writes to the same data entry from multiple parallel writers. Furthermore, database storage formats are opaque and non-portable, and no file standard exists to facilitate the movement of data from one database system to another. By contrast, NetCDF and HDF5 both offer open, standardized formats and portable, self-describing binary formats for storing data represented as Object Databases.

Grant applications are sought to develop tools that enable seamless transfer of data from ODBMSs to self-describing scientific data file formats such as NetCDF and HDF5 and vice-versa. Approaches of interest should (1) enable a level of tool integration and migration in the commercial space that currently is not available, and (2) offer the scientific community access to a broad array of robust data management tools and much more powerful query-driven data analysis capabilities.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

37d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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Subtopic b:

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5. NetCDF (Network Common Data Form). (URL: http://www.unidata.ucar.edu/software/netcdf/)

6. Parallel NetCDF. (URL: http://cucis.ece.northwestern.edu/projects/PNETCDF/)

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Subtopic c:

7. Hierarchical Data Format (HDF). (URLs: http://eosweb.larc.nasa.gov/HBDOCS/hdf.html and http://en.wikipedia.org/wiki/Hierarchical_Data_Format)

8. Analytics: Scientific Data Management. (URL: http://www.nersc.gov/nusers/analytics/sdm/)

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38. MODELING AND SIMULATION OF INDUSTRIALLY-RELEVANT PROBLEMS

Over the past 30 years, the Department of Energy's (DOE) supercomputing program has played an increasingly important role in scientific research by allowing scientists to create more accurate models of complex processes, simulate problems once thought to be impossible, and analyze the increasing amount of data generated by experiments. Computational science has become the third pillar of science, along with theory and experimentation. However, despite the great potential of modeling and simulation to increase understanding of a variety of important engineering challenges, High Performance Computing (HPC) is underutilized by industry.

Grant applications are sought in the following subtopics:

38a. Simulation of Engineering Problems

Numerous engineering problems ranging from the design of new materials, to understanding ways to efficiently generate energy from wind, hydro, combustion, and nuclear sources have relevance both to industry and to the mission of DOE. Simulation studies, in conjunction with physical experiments and theoretical models, provide deeper insights than experiments and theory alone. Thus scientists gain a better understanding of these complex problems. Grant applications are sought for the simulation of engineering problems that have relevance both to industry and to the mission of DOE. Approaches of interest include, but are not limited to, simulations:

- that delve into the structure of materials at the atomic and molecular level promoting the development of materials with new properties;
- of three-dimensional unsteady fluid flows, such as the flow over wind-turbine blades;
- of unsteady combustion, such as near blow-off dynamics;
- of combustion instability in gas-turbine combustors;
- aimed at an improved understanding of the environmental impact of energy-production technologies;

- to guide the development or monitoring of nuclear energy generation and management technology, including (1) extending the life of existing nuclear plants, (2) building and operating new reactors of advanced designs, (3) developing new uses for nuclear energy, such as producing hydrogen, and (4) dealing with nuclear waste;
- that facilitate procedures and patient monitoring for nuclear medicine;
- that support development and/or monitoring of carbon sequestration methods and technology;
- involving yield predictions for biofuel feedstocks; and
- of two-phase flows, such as fuel sprays for internal combustion engines.

Grant applications must establish how the proposed research relates to the achievement of one or more energy-related goals, such as improved energy efficiency, reduced emissions, development of green energy alternatives, and/or reduced costs for environmentally-friendly energy technologies.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

38b. High Performance Framework for Agent Based Simulation Modeling

An Agent Based Model (ABM) describes the dynamics of a system by representing it as a collection of interacting concurrent synchronous and asynchronous objects called agents that adapt as the system dynamics evolve. Individual agents are typically characterized as boundedly rational, presumed to act strategically in their own interests, using heuristics or simple decision-making rules. Agent adaptation may entail learning, reproduction, and modified behavior. Each agent may have very simple dynamics and a finite internal state, and yet the combined interaction of all agents can create rich emergent behaviors [Axtel1999], [Bonebeau2002], [Allan2009], and [Allan2009-2]. With ABM models, one can study emergent behaviors in complex, adaptive systems. Low level (micro) interactions result in high level (macro) behavior that are not easily predicted by other modeling methods and are often very counter-intuitive. Several software frameworks have been developed that enable easy implementation of ABM models. Several well known frameworks like Swarm [Burkhart1994], Repast [North2006], MASON [Luke2005], and NetLogo [Wilensky1999] have been developed. Desktop toolkits are essentially discrete-event simulators [Ziegler2000], where agent actions are modeled as discrete-events and a scheduler queues all events to be processed for a given time step and executes them one at a time in a serial fashion on the CPU. Clearly, the simulation of large sized ABMs with millions of agents is not feasible on these toolkits. Cluster-based toolkits such as [Massaioli2005] and [Scheutz2006] make use of distributed memory processors communicating through high-speed network connections. Given the high levels of communication among interacting agents, cluster based parallel ABM models have not delivered scalable performance. A recent development is the use of data-parallel algorithms on GPUs for ABM simulation. See [Richmond2009], [Richmond2009-2], [Millan2007], [Lysenko2007], and [Mariam2010]. However, in order to make full use of the computing power and bandwidth, all computation have to be restricted to the GPU with minimal communication with the CPU, rendering this approach less than ideal for large ABM models.

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Research on ABM toolkits for petascale or exascale computing platforms has been pursued at DOE Labs: http://www.dis.anl.gov/groups/cas.html at Argonne, and ABM software ASIM at LBNL, in collaboration with University of New Mexico: http://www.tp.umu.se/~holme/~asim/ Grant applications are sought for the development of generic, highly customizable agent based modeling toolkits that take advantage of high performance computing platforms at petascale and are shown to scale to exascale platforms.

Approaches of interest include, but are not limited to ABM toolkits that:

- optimize communications and synchronization of concurrent agents, scaling to current and future parallel platforms;
- have novel algorithms for handling mobile agents, agent ordering and collision, and agents death and replication as part of a parallel toolkit;
- integrate run-time statistics to a parallel toolkit;
- integrate visualization of macro behavior to a parallel toolkit;
- integrate experiment configuration and history to a parallel toolkit;
- provide verification and validation methods for parallel toolkits.

Grant applications must establish how the proposed toolkit can significantly improve simulation modeling capabilities in energy-related goals, such as energy efficiency, reduced emissions, development of green energy alternatives, and/or reduced costs for environmentally-friendly energy technologies.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

38c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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39. 100 GigE NETWORKING COMPONENTS

There is a growing anticipation of a data deluge generated by extreme-scale computing and by large–scale science experiments. Some forecasters predict the total amount of data per experiment will excess of a Zetabyte in the next decade. Data volume of this size will hold the key to major scientific discoveries. However, existing scientific facilities (networks, storage systems, file systems, end-host system software) are unprepared to handle this volume of data. At this scale, existing network infrastructures that support large-scale science activities will require 1,000x performance scaling. To begin to address these concerns, DOE's ESnet (Energy Sciences Network) is currently deploying a national backbone based on state-of-the-art 100 Gbps technologies. While this new infrastructure will carry shared IP based traffic, it is expected that ESnet will migrate to a hybrid IP/circuit infrastructure using 100 Gbps technologies and services in the near future. The goal will be to achieve to **terabit-scale** end-to-end network infrastructures for the open science community.

Cyber-security at 100 Gbps is unexplored territory, and the development of solutions in this space will be challenging. For example, the 100 Gbps security systems must not impede the high-speed data flows, such as the requirement for 100 Gbps line rate or "wire-speed" operation, on which large-scale science depends. In addition, the difference between Enterprise traffic (e.g. day-to-day business web and email) traffic – which is assumed to be the operational profile for many commercial cyber security solutions – and science traffic will be even greater at 100Gbps, since science traffic has grown to be the dominant user of ESnet. Dealing with this traffic mix will present unique challenges to traditional cyber-security systems.

To address these challenges, grant applications that will lead to software and hardware sub-systems are sought in the following subtopics:

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39a. 100 Gbps Traffic Engineering Generators

The development of 100 Gbps network components (i.e., software, hardware, protocols, cyber-systems) will require testbeds for capability and performance validation. A critical component of these testbeds is a cost-effective traffic generator that can emulate real-world traffic at various networking layers, especially at layers 1 - 4. Multi-layer traffic generators are also critical in debugging network failures in operational networks such as ESnet. They can be use to inject artificial traffic in network during fault diagnosis. Respondents to this topic are encouraged to take into considerations the relevant industry standards, such as the IEEE 10 GigE, 40 GigE, 100 GigE, and the ITU G709, when designing a multi-layer traffic generator.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

39b. Multi-Layer Traffic Capture Systems at 100 Gbps

Network traffic capture capabilities at the packet layer provide the basis for many types of network services including intrusion detection, deep packet inspection, and network monitoring. Numerous packet capture systems work effectively at speeds up to 1 Gbps while some systems scale to10 Gbps with some difficulties. With the advent of as100 Gbps link technologies, packet capturing at these rates will even be more difficult. Additionally, while current traffic capture systems operate mostly at the packet level, in a multi-layer hybrid network, it will also be useful to capture traffic at other layers (layer 1, 2, 3) as well. Grant applications are sought that address these scaling issues.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

39c. NIDS Front-End for Load Balancing at 100 Gbps

A number of DOE Labs, as well as a number of universities, use the Bro Intrusion Detection System (IDS). In order for the Bro IDS to operate on network links that exceed 1 Gbps, a scalable Bro cluster, known as NIDS has been developed and demonstrated to be scalable on the analysis backend. However, for NIDS's that do traffic analysis on links of 10Gbps and above, a front-end system, which performs load-balancing to split the analysis across multiple commodity systems on the backend, are now required. Proposed front-end systems, hardware and/or software, could provide scalable and manageable NIDS systems that operate on high-performance networks without significantly impacting the flow of legitimate science data. Therefore, grant applications are sought to develop a NIDS front-end capable of load balancing packets on 100 Gbps links, including 100-Gbps-capable hardware that is compatible with NIDS.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

39d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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40. HIGH PERFORMANCE COMPUTING SYSTEMS

Developing methods to fully utilize large scale supercomputers is a fundamental task for the DOE ASCR office. Current systems are based on tens to hundreds of thousands of commodity processors, petabytes of disk and archival tape storage, and specialized display and visualization devices. Tools and software that simplifies the process of building, running, and debugging applications that run on these supercomputers, dealing with the complexity of multi-core processors, and dealing with system faults are all elements of this program. Proposals are solicited that in the following subtopic areas.

40a. Computing Applications Porting

There is a growing need for a broad range of scientific and engineering application software that can be utilized on terascale and petascale computer systems. Currently, few commercial vendors are addressing this need. Grant applications are sought to develop technology for porting applications to a myriad of High Performance Computing (HPC) platforms. Proposed approaches could involve scaling studies, algorithm re-design, software re-architecting, software testing, and design changes, in order to tune and optimize the use of applications on these massively parallel supercomputing systems. Some specific topics of interest in this area include:

- Moving legacy codes to new architectures and new machines.
- Writing new codes to accomplish new powerful capabilities.
- Formulation of new approaches to solve known problems on large scale platforms.
- Algorithm development to convert the new formulations into viable, hardware architecture-aware codes.
- Methods to assure efficiency and scalability across a broad horizon of applications and algorithms.
- Embracing multiple cores and accelerators in massively parallel architectures.
- Methods for verification and validation that lead to certification of codes.

Research related to these topics should be led by software providers. Collaborations with DOE laboratories – in the form of access to HPC resources, as well as in providing expertise in targeted science and engineering domains – may prove to be quite beneficial.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40b. Multicore OS Technology

Current operating systems (OS), such as Linux, are designed to work exclusively on low-concurrency homogeneous multicore systems. However, current technology trends are moving towards heterogeneous multicore environments that exhibit massive parallelism (not anticipated by Linux) and complex memory hierarchies that are not necessarily cache-coherent (such as Cell, and GPUs). Also, High Performance Computing (HPC) OS solutions require a modular approach to OS design that would allow OS services to be configured in flexible

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manner, in order to meet the needs of each individual application – as opposed to the current all-or-nothing approach where micro-kernels offer minimal services (providing more memory to the application and to minimize OS jitter) and full OSs are required to offer robust scripting environments (at a cost of memory footprint and complexity). HPC users need a dynamically configurable OS environment – a modular configurable platform – to meet these diverse requirements. It is unlikely that incremental changes to conventional OS implementations will result in a solution that meets these emerging requirements. The DOE FastOS program has demonstrated initial technological approaches to OS technology that are capable of operating on non-conventional memory hierarchies and heterogeneous "accelerator" based platforms. Grant applications are sought to bring such approaches into a mainstream turn-key OS solution that offers value to the broader HPC environment. Grant applications also should demonstrate the applicability of the proposed approach to embedded/consumer-electronic devices, which also are sensitive to memory requirements, and are increasingly concerned with performance and management of scheduling for parallel hardware.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40c. Compiler Research for Code Instrumentation

Understanding the cache-footprint and memory bandwidth requirements for a given code is essential for (1) setting the parameters for future High Performance Computing (HPC) system designs, and (2) optimizing system parameters to develop energy-efficient computing designs that do not compromise computational efficiency. However, understanding these parameters using conventional PAPI or other performance-counter-based tools has proven to be extremely difficult and inaccurate over time. Also, the performance-counter infrastructure provided by modern microprocessor designs tends to be very narrow in scope and incomplete for the task of fully understanding code requirements. Grant applications are sought to create compilers capable of integrating performance instrumentation directly into application codes that can work in conjunction with PAPI and hardware performance counters, so that performance data can be gathered transparently at runtime and then fed-back to a re-compilation process that would further optimize code for subsequent runs on HPC systems. Grant applications also should address how this same instrumentation data could be used to (1) better understand the DOE workload, and (2) provide guidance for the hardware design of future HPC systems (e.g. cache-sizes, instruction mix, memory bandwidth requirements, and communication requirements).

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40d. Journal-based Storage for Parallel I/O

In the research community, the advantages of a journaling approach to scalable parallel I/O systems has been demonstrated by a number of examples, including the Parallel Log-Structure File system (http://institute.lanl.gov/plfs/) and PVFS2. This approach is substantially different from current parallel file systems, such as GPFS and LUSTRE. The commercialization of these journal-based file systems would offer the opportunity to significantly improve the performance of High Performance Computing (HPC) I/O subsystems, and could provide substantial opportunities for non-HPC applications as well. However, such file systems require significant advances in management infrastructure and robustness before they can be migrated into commercial solutions. Therefore, grant applications are sought to develop robust, commercially-viable implementations of journal-based file systems that have the security and management capability necessary for broad system deployment and commercial application.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40e. Advanced, Multi-platform Build Systems

Currently, build systems are the weakest link in portable High Performance Computing (HPC) codes and library design. Despite language standardization, and POSIX library standardization, it is extraordinarily difficult to design application build environments that are portable across the broad-variety of HPC systems. As a symptom of the poor quality of today's build environments, the failure of many application builds is due to an inability to locate the library that contains the implementation of a particular subroutine call that matches the needs of a user application. The remedy is to globally search for the missing implementation by using various UNIX system tools. Part of the problem is that the current symbol resolution depends on the use of flat-file representations of rather than on the use of a more search-driven database storage format. Grant applications are sought to create advanced build systems and symbol resolution frameworks that are capable of storing all library subroutine calls, related data-structures, and global variables in a query-able database representation, in order to facilitate more productive and portable build environments.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40f. Commercialization of HPC Programming Environments

Within the HPC program, considerable effort has gone into the creation of Integrated Development Environments (IDEs) and programming tools. For example the Photran extension to the Eclipse IDE enables automatic analysis of Fortran+MPI code for parallel systems. However, an additional effort is required to integrate this environment with existing HPC system environments at the Leadership Computing Facilities and other HPC environments. Therefore, grant applications are sought to further the commercialization of IDEs (such as the Eclipse IDE for MPI+Fortran applications) so that they can be integrated into mainstream practice at computing clusters and other leading-edge "leadership" HPC environments.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40g. Portable Linux Distributions for HPC

Linux-based login and batch queue environments are prevalent in High Performance Computing (HPC) environments. However, differences in deployments, in configuration across clusters, and in parallel computing resources present challenges to the portability and ease of use of HPC software. Therefore, grant applications are sought to develop a Linux distribution technology that brings together several important HPC software portfolios. Approaches of interest include the development of:

A software suite – including SciDAC supported codes such as Chombo, PETSc, Zoltan, ScaLAPACK, Hypre, Sundials, VisIt, GridFTP, Metis, and others in common use at HPC centers. Such a suite could provide valuable enhancements to software users and maintainers, if it were organized as a well tested set of version-controlled software modules. RPMs may be one way to accomplish this goal.

A fully working set of open source compilers, MPI, HPC libraries, and performance tools, layered on top of an existing Linux distribution. Such a set could provide a turn-key solution for the HPC space. Commercial software also could be bundled as part of that product.
An operating system image that integrates the pieces of a full featured HPC environment, and is suitable for booting as a live CD or in a virtual machine. Such an image could bring SciDAC supported software to the desktop, small clusters, and cloud computing environments; could bridge the gap between those environments and petascale computing; could be used pedagogically to "bring HPC to your laptop"; and could grow into a profound tool for HPC interoperability.

An interface that brings HADOOP (open source map-reduce software) to parallel computers with batch queue environments. Most HADOOP instances are set up on clusters designed around search functions and are operated in a persistent manner as opposed to a time-shared manner. In a batch queue environment, the situation would be very different; the HADOOP infrastructure would need to be instantiated and shutdown within each job. An easy on/off HADOOP would make it easier for scientists to search and analyze their data.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40h. Software Fault Detection

Software errors are the dominant mode of service interruption over the lifetime of most HPC resources. The development of software that tracks and analyzes software faults in an organized way could yield valuable benefit to users and managers of HPC resources. Therefore, grant applications are sought to develop:

Low level mechanisms to conduct detailed unit testing, benchmarking, and pattern detection of software faults. Such mechanisms could be integrated into a high level data center dashboard, thereby minimizing the staff effort required to track failures on the basis of log files and after-the-fact examination. Although datacenter dashboards already exist, most are focused on transaction processing rather than on parallel computing. Likewise, existing work has emphasized revenue rather than scientific metrics, detailed application performance, and parallel efficiency.

Change management software that gathers and records software and configuration data over time. Such data could be joined with benchmark or workload data to provide a perspective on how software upgrades and configuration changes can impact performance.

In addition, there is a need to develop software for fault analytics. When a large parallel computer is booted, many layers of software start in sequence, without checking to see that the resources, files, and services that they require are indeed available. One consequence is that one layer may freeze or malfunction, leading to an ensuing cascade of events that may require human intervention to unwind. Therefore, grant applications also are sought for a mechanism to detect (or manually enter) software dependencies on an HPC resource and translate those

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dependencies into basic unit tests that can be used to check a machine's degree of readiness for production use. Such dependency tests could be useful both before and after a fault. Similarly, when a software fault occurs, such tests could be invoked to obtain a richer assessment of the situation surrounding the fault. (In some cases, the level of detail is not very rich – only a single number or error code – which leads to difficulties in determining why a job failed.) Although an appropriately trained system administrator can read the logs and often diagnose the failure, an automated system is preferred.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40i. Composition of heterogeneous concurrent components

High performance computing (HPC) and embedded system computing have been two very distinct areas in computer science R&D. The hardware and software environment for these two areas target separate markets, support very different applications and workloads, with different performance concerns. Design philosophies and design tools created by these two diverse R&D communities have been radically different. However, given the advent of multi-core processors with their inherent power and memory constraints, the boundary between these two areas is beginning to blur. It is no longer feasible (technically and economically) to simpler procure faster machines with bigger memories to support the HPC workload.

The rigorous analysis and design tools used to co-design embedded systems hardware and software have matured significantly over the last four or five decades. Their success, dealing with very stringent systems constraints, appears to be a fertile ground to develop new philosophies and tools that can meet the power, memory, and flops requirements of HPC at Exascale. The more recent and significant advances made in embedded systems R&D were due to the formal development of models of computation used to express heterogeneous concurrent components and the theoretically sound approach to the composition of these heterogeneous components to simulate, analyze, and design systems.

Leveraging and adapting these advances to HPC necessarily entails discovering new or adapting existing models of computation to the particular characteristics of HPC, building abstractions and mechanisms into tools that support the HPC models of computation and their composition, and experimenting with these new concepts and tools in hardware and software co-design for HPC systems. Therefore, grant applications are sought that explore these concepts in merging HPC and embedded systems design to create new HPC computing environments.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

40j. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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41. COLLABORATION, SCIENTIFIC VISUALIZATION AND DATA UNDERSTANDING

Scientific visualization and data management are critical enabling technologies for computational science research, providing scientists with the capability to extract scientific insights from data sets generated by simulations and experiments. The combination of sensor networks, high-end computing, and more experiments are expected to generate several petabytes of structured and unstructured multi-dimensional data sets per year. Thus, the next-generation of scientific visualization systems will have to outperform today's systems. This topic seeks visualization and collaborative data analysis systems that are attuned to the needs of domain scientists and/or decision makers and address important data management and domain-specific science challenges. Limited computer resources at DOE facilities can be made available to successful Phase I applicants for proof-of-concept studies, if properly justified in the grant application. Additional computer resources also can be made available during Phase II to further develop the proposed concepts.

Grant applications are sought in the following subtopics:

41a. Collaborative Data Analysis and Visualization

Advances in high performance network capabilities and collaboration technologies are making it easier for large geographically-dispersed teams to collaborate effectively. Despite these advances, efforts to mitigate the effects of separation have not kept pace with the advance of technology, especially for research teams that use major computational resources, data resources, and experimental facilities supported by DOE.

While the importance of collaboratories is expected to increase in the future, significant barriers must be overcome for collaboratories to achieve their potential. In particular, research and development efforts are needed to provide (1) remote access to facilities that produce petabytes/year; (2) remote users with an experience that approaches "being there;" (3) remote visualization of large-scale data sets from computational simulation; and (4) effective remote access to advanced scientific computers. In addition, to be part of a useful investigatory scientific research environment or an instructional environment, visualization systems and data analytics must be integrated with supporting computational science technologies such as high-end computing, data management, data storage/retrieval, I/O capabilities, and networking capabilities.

Grant applications are sought to develop (1) technology to significantly enhance interaction between users, systems, and software; (2) an infrastructure that can enable both synchronous and asynchronous collaborative interactions between users in the process of doing science; and (3) communications capabilities that can create a sense of participation and knowledge sharing, along with novel display technologies such as 3D autostereo.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

41b. Comparative Visualization

Multiple research models, and even production-class codes, are often run as an ensemble set that provides a higher-confidence output than an individual model or code. Similarly, researchers seeking to validate models or experimental measurements, or to perform parameter studies and sensitivity analyses, generate multiple instances of data sets, which need to be compared and/or analyzed as a set. Frequently, analysts and decision makers need to compare the outcomes of analytical processes and/or differences between data sets. Despite these comparison needs, many studies have documented the very poor human capability for detecting change visually, a phenomenon known as change-blindness. Therefore, grant applications are sought to develop algorithms and software systems that provide comparative visualizations, or visual representations of the differences between data sets and/or processing outcomes.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

41c. Distance/Remote Visualization

The capability for scientists to analyze, visualize, interact with, and understand their research results is critical to effective science. Yet, these activities are significantly hampered by the fact that the scientists often are in geographically different locations than the supercomputing resources they work on. As we move to larger-scale computing, this problem will become more severe, because of the need to move even more data over a network. Therefore, grant applications are sought to develop products to address these visualization needs. Approaches of interest include, but are not limited to, the development of (1) latency-tolerant software applications for delivering interactive visualization results to remote consumers, using distributed and parallel computational platforms; (2) software applications for delivering visualization results that gracefully accommodate the wide variance in network capacity; and (3) middleware applications for resource- and condition-adaptive partitioning of the visualization pipeline to meet performance or capability targets.

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Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

41d. Interactive Visualization and Analytics

Human learning and insight are active processes that require more than examining an image; yet, although it is assumed that existing visualization systems support knowledge discovery, in fact, they just present graphics. Typically the visualizations are not deeply integrated with methods and tools that would enable insight into the processing of the data. Existing systems also lack the ability to (1) allow users to interactively explore data to facilitate discovery, and (2) capture the process of visual analysis and interaction, in order to enable validation and provide insight into best practices.

Grant applications are sought for new software applications and tools that enable integrated interactive visualization and analytic discovery. Approaches of particular interest include, but are not limited to (1) network visualization and analysis, including computer networks, sensor networks, power grids, social networks, etc; (2) computational fluid dynamics; and (3) high-end computer system performance.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

41e. Techniques for Integration and Interactive Visual Analysis of Multi-Disciplinary Scientific Data

Today's scientific applications include data from multiple disciplines, such as (1) an ecological study that includes chemistry, biology, and earth science data; or (2) a climate study that includes data about the atmosphere, oceans, sun spots, glaciers and ice dynamics, hydrology, human populations, etc. Grant applications are sought to develop novel products for integrating such data for the purpose of common examination and analysis. Approaches of interest include, but not limited to, integration and interoperability across multiple spatio-temporal scales, heterogeneous data formats, etc.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

41f. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Richard Carlson, 301-903-9486, rcarlson@ascr.doe.gov

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42. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Large scale data storage and processing systems are needed to store, access, retrieve, distribute, and process data from experiments conducted at large facilities, such as Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC) and the Thomas Jefferson National Accelerator Facility (TJNAF). In addition, data acquisition for next the generation rare isotope beam accelerator facility (FRIB) accelerator requires unprecedented speed and flexibility in collecting data from new flash ADC based detectors. The experiments at such facilities are extremely complex, involving thousands of detector elements that produce raw experimental data at rates up to a GB/sec, resulting in the annual production of data sets containing hundreds of Terabytes (TB) to Petabytes (PB). Many 10s to 100s of TB of data per year are distributed to institutions around the U.S. and other countries for analysis. Research on large scale data management systems and high speed, distributed data acquisition is required to support these large nuclear physics experiments. All grant applications must explicitly show relevance to the nuclear physics program.

Grant applications are sought in the following subtopics:

42a. Large Scale Data Storage

The cost of data storage in magnetic disk media is now competitive with magnetic tape for storing large volumes of data. Because current technology keeps all disk drives powered and spinning, the infrastructure costs of operating a many-petabyte-scale disk storage system could be prohibitive. However, one characteristic of nuclear physics datasets is that most of the data is accessed infrequently. Therefore, grant applications are sought for new techniques for petabyte-scale magnetic disk systems that are optimized for infrequent data access, emphasizing lower cost, lower power usage, and low access latency to frequently used data. To the extent feasible, it is desirable that the cost should scale with the amount of data accessed rather than the total storage capacity.

Also, many DOE labs have existing investments in large-scale tape robot technologies, which are at this point the most cost-effective way to store petabyte-sized datasets. Grant applications are sought for (1) the development of innovative storage technologies that not only can use existing cartridge and tape formats but also will significantly increase the storage density and capacity, increase data read and write speeds, or decrease costs; and (2) innovative software technologies to allow file-system-based user access to petabyte-scale data.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

42b. Large Scale Data Processing and Distribution

A recent trend in nuclear physics is to construct data handling and distribution systems using web services or data grid infrastructure software – such as Globus, Condor, SRB, and Open Grid

Services (OGSA), which is based upon Web Services – for large scale data processing and distribution. Grant applications are sought for (1) hardware and/or software techniques to improve the effectiveness and reduce the costs of storing, retrieving, and moving such large volumes of data, including, but not limited to, automated data replication coupled with application data catalogs, data transfers to Tier 2 and Tier 3 centers from multiple data provenance – with an aim for least wait-time and maximal coordination (coordination of otherwise chaotic transfers), distributed storage systems of commercial off-the-shelf (COTS) hardware, storage buffers coupled to10 Gbps (or greater) networks, and end-to-end monitoring and diagnostics of WAN file transport; (2) hardware and/or software techniques to improve the effectiveness of computational and data grids for nuclear physics – examples include integrating the management of distributed open source Relational DataBase Management System (RDBMS) with OGSA, and developing application-level monitoring services for status and error diagnosis; (3) effective new approaches to data mining, automatic structuring of data and information, and facilitated information retrieval; and (4) distributed authorization and identity management systems, enabling single sign-on access to data distributed across many sites. Proposed infrastructure software solutions should consider and address the advantages of integrating closely with relevant components of Grid middleware, such as the Virtual Data Toolkit (VDT), as the foundation used by nuclear physics and other science communities. Applicants that propose data distribution and processing projects are encouraged to determine relevance and possible future migration strategies into existing infrastructures.

Grant applications also are sought (1) to provide redundancy and increased reliability for servers employing parallel architecture, so that they are capable of handling large numbers of simultaneous requests by multiple users; (2) for hardware and software to improve remote user access to computer facilities at nuclear physics research centers, while at the same time providing adequate security to protect the servers from unauthorized access; and (3) for hardware and software to significantly improve the energy efficiency and reduce the operating costs of computer facilities at nuclear physics research centers.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

42c. Grid and Cloud Computing

Grid deployments such as the Open Science Grid (OSG) in the U.S. and the Worldwide Large Hadron Collider (LHC) Computing Grid (WLCG) in Europe provide standardized infrastructures for scientific computing across large numbers of distributed facilities. To support these infrastructures, new computing paradigms have begun to emerge: (1) Grid Computing, sometimes called "computing on demand," which supports highly distributed and intensive scientific computing for nuclear physics (and other sciences); and (2) Cloud Computing, which could offer an application-specific computing environment by allowing the deployment of application-requested virtual machines. Accordingly, there is a need for compatible software distribution and installation mechanisms that can be automated and scaled to the large numbers (100s) of computing facilities distributed around the country and the globe. Grant applications are sought to develop mechanisms and tools that enable efficient and rapid packaging, distribution, and installation of nuclear physics application software on distributed computing facilities such as the OSG and WLCG. Software solutions should enable rapid access to

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computing resources as they become available to users that do not have the necessary application software environment installed.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

42d. Software-driven Network Architectures for Data Acquisition
Modern data acquisition systems are becoming more heterogenous and distributed. This presents new problems in synchronization of the different elements of this event-driven architecture. The building blocks of the data acquisition system are digitizers, either flash digitizers or integrating digitizers of time, pulse height or charge. These elements respond in real-time to electrical signals from detectors. Information from these elements is used to determine if something interesting has happened, that is, forming a trigger. The data in each element is labeled with a properly synchronized time. Finally, the data from the elements are assembled together for later analysis, called Event Building. At present the elements tend to be connected by buses (VME, cPCI), custom interconnects or serial connections (USB).

A data acquisition system ultimately composed of separate ADC's for each detector element, connected by commercial network or serial technology, is envisioned. Development is required to implement the elements of this distributed data acquisition over commercially available network technologies such as 10 Gb Ethernet or ATCA. The initial work needed is to develop an architecture that works efficiently in the network bandwidth and latencies. The elements desired in the architecture are to (1) synchronize time to a sufficient precision, as good as 10ns or better to support FADC clock synchronization, less precise to support event building, (2) determine a global trigger from information transmitted by the individual components (3) notify the elements to locally store the current information, (4) collect event data from the individual elements to be assembled into global events and (5) software tools to validate the function of the synchronization, triggering and event building during normal operation. The synchronization of time is critical to the success of this architecture, as is the constant validation of the synchronization.

The architecture would specify the functional model for individual elements of the system, the high level network protocols, and requirements on the communications fabric for given data rates and system latencies. At FRIB, low event rates of 1 to 10 kevents/s are anticipated, with large data streams from FADC-based detector systems. The large latencies possible in highly buffered flash ADC architectures can be used to advantage in the design of the architecture. A portable software implementation of the elements would be the next step in the development.

Such an architecture and its implementation could form the basis of a standard for next generation data acquisition in nuclear physics, particularly at the FRIB.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

42e. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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43. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

The DOE Office of Nuclear Physics seeks developments in detector instrumentation electronics with improved energy, position, timing resolution, sensitivity, rate capability, stability, dynamic range, durability, pulse-shape discrimination capability, and background suppression. Of particular interest are innovative readout electronics for use with the nuclear physics detectors described in Topic 45 (Nuclear Instrumentation, Detection Systems, and Techniques). All grant applications must explicitly show relevance to the nuclear physics program.

Grant applications are sought in the following subtopics:

43a. Advances in Digital Electronics

Digital signal processing electronics are needed to replace analog signal processing in nuclear physics applications. Grant applications are sought to develop: fast digital processing electronics that improve the accuracy of the analog electronics, such as in determining the position of interaction points (of particles or photons) to an accuracy smaller than the size of the detector segments. Emphasis should be on circuit technologies with low power dissipation.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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43b. Circuits

Grant applications are sought to develop custom-designed integrated circuits, as well as circuits (including firmware) and systems, for rapidly processing data from highly-segmented, position-sensitive germanium detectors (pixel sizes of approximately 1 cm^2) and from particle detectors (e.g., gas detectors, scintillation counters, silicon drift chambers, silicon strip detectors, particle calorimeters, and Cherenkov counters) used in nuclear physics experiments. Areas of specific interest include (1) representative circuits such as low-noise preamplifiers, amplifiers, peak sensors, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) multiple-sampling application-specific integrated circuits (ASICs), to allow for pulse-shape analysis; (3) readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample-and-hold integrated circuits; (4) systems with exceedingly large dynamic range (> 5000) employing, for example, either dynamic CSA gain changing or combinations of a standard linear CSA with a time-over-threshold (TOT) that works well into CSA saturation; and (5) constant-fraction discriminators with uniform response for low- and high energy gamma rays. These circuits should be fast; low-cost; high-density; configurable in software for thresholds, gains, etc.; easy to use with commercial auxiliary electronics; low power; compact; and efficiently packaged for multi-channel devices.

In addition, planned luminosity upgrades at RHIC will require fine-grained vertex and tracking detectors (both silicon and gas) for high particle multiplicity environments. Therefore, grant applications are sought for advances in microelectronics that are specifically designed for low-noise amplification and processing of detector signals, and that are suitable for these next generation detectors. The microelectronics and associated interconnections must be lightweight and have low power dissipation. Of particular interest are designs that minimize higher-gate leakage currents due to tunneling and maintain dynamic range.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

43c. Advanced Devices and Systems

Grant applications are sought for improved or advanced devices and systems used in conjunction with the electronic circuits and systems described in subtopics a and b:
Areas of interest regarding devices include (1) radiation-hardened, wide-bandgap semiconductors (i.e., semiconductor materials with bandgaps greater than 2.0 electron volts, including Silicon Carbide (SiC), Gallium Nitride (GaN), and any III-Nitride alloys); (2) inhomogeneous semiconductors such as SiGe; and (3) device processes such as silicon-on-insulator (SOI) or silicon-on-sapphire (SOS).
Areas of interest regarding systems include (1) bus systems, data links, event handlers, multiple processors, trigger logics, and fast buffered time and analog digitizers. For detectors that generate extremely high data volumes (e.g., >500 GB/s), (2) advanced high-bandwidth data links are of interest.

Grant applications also are sought for generalized software and hardware packages, with improved graphic and visualization capabilities, for the acquisition and analysis of nuclear physics research data.

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Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

43d. Active Pixel Sensors

Active Pixel Sensors in CMOS (complementary metal-oxide semiconductor) technology are replacing Charge Coupled Devices as imaging devices and cameras for visible light. Several laboratories are exploring the possibility of using such devices as direct conversion particle detectors. The charge produced by an ionizing particle in the epitaxial layer is collected by diffusion on a sensing electrode in each pixel. The charge is amplified by a relatively-simple low-noise circuit in each pixel and read out in a matrix arrangement. If successful, this approach would make possible high-resolution, position-sensitive particle detectors with very low mass (approximately 50 microns of silicon in a single layer). This approach would be superior to the present technology that uses a separate silicon detector layer, which is bump-bonded to a CMOS readout circuit. Grant applications are sought to advance the development of integrated detector-electronics technology, using CMOS monolithic circuits as particle detectors. The new active pixel detector with its integrated electronic readout should be based on a standard CMOS process. The challenge is to design a sensor with low noise readout circuits that have sufficiently high sensitivity and low power dissipation, in order to detect a minimum ionizing particle in a thin "epitaxial-like" or equivalent layer (~10-30 microns).

Grant applications also are sought for the next generation of active pixel sensors, or even strip sensors, which use the bulk silicon substrate as the active volume. This more advanced approach would have the advantage of developing relatively larger signals and allowing sensitivity to non-minimum ionizing particles, such as MeV-range gamma rays.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

43e. Manufacturing and Advanced Interconnection Techniques

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

In addition, many next-generation detectors will have highly segmented electrode geometries with 5-5000 channels per square centimeter, covering areas up to several square meters. Conventional packaging and assembly technology cannot be used at these high densities. Grant applications are sought to develop (1) advanced microchip module interconnect technologies that address the issues of high-density area-array connections – including modularity, reliability, repair/rework, and electrical parasitics; (2) technology for aggregating and transporting the signals (analog and digital) generated by the front-end electronics, and for distributing and conditioning power and common signals (clock, reset, etc.); (3) low-cost methods for efficient cooling of on-detector electronics; (4) low-cost and low-mass methods for grounding and shielding; and (5) standards for interconnecting ASICs (which may have been developed by

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diverse groups in different organizations) into a single system for a given experiment – these standards should address the combination of different technologies, which utilize different voltage levels and signal types, with the goal of reusing the developed circuits in future experiments.

Lastly, highly-segmented detectors with pixels smaller than 100 microns present a significant challenge for integration with frontend electronics. New monolithic techniques based on vertical integration and through-silicon vias have potential advantages over the current bump-bonded approach. Grant applications are sought to demonstrate reliable, readily-manufacturable technologies to interconnect silicon pixel detectors with CMOS front-end integrated circuits. Of highest long term interest are high-density high-functionality 3D circuits with direct bonding of high resistivity silicon detector layer of an appropriate thickness (50 to 500 microns) to a 3D stack of thin CMOS layers. The high resistivity detector layer would be fully depleted to enable fast charge collection with very low diffusion. The thickness of this layer would be optimized for the photon energy of interest or to obtain sufficient signal from minimum ionizing particles.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

43f. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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44. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC), with heavy ion beam energies up to 100 GeV/amu and polarized proton beam energies up to 250 GeV; technologies associated with RHIC luminosity upgrades; the development of an electron-ion collider; linear accelerators such as the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF); and development of devices and/or methods that would be useful in the generation of intense rare isotope beams for the next generation rare isotope beam accelerator facility (FRIB). A major focus in all of the above areas is superconducting radio frequency (RF) acceleration and its related technologies. Relevance of applications to nuclear physics must be explicitly described. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. All grant applications must explicitly show relevance to the nuclear physics program.

Grant applications are sought in the following subtopics:

44a. Materials and Components for Radio Frequency Devices

Grant applications are sought to improve or advance superconducting and room-temperature materials or components for RF devices used in particle accelerators. Areas of interest include (1) peripheral components, for both room temperature and superconducting structures, such as ultra high vacuum seals, terminations, high reliability radio frequency windows using alternative materials (e.g., sapphire), RF power couplers, and magnetostrictive or piezoelectric cavity-tuning mechanisms; (2) fast ferroelectric microwave components that control reactive power for fast tuning of cavities or fast control of input power coupling; (3) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (4) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment, which simplify procedures and reduce costs associated with repair and modification; (5) more cost effective, kW-to-multiple-kW level, liquid helium refrigerators; (6) simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 and/or 4.5 K; (7) alternative cavity fabrication techniques, such as hydro forming or spinning of seamless SRF cavities; and (8) novel SRF linac mechanical support structures with low thermal conductivity and high vibration isolation and strength.

Grant applications also are sought to develop (1) methods for manufacturing superconducting radio frequency (SRF) accelerating structures with $Q_0 > 10^{10}$ at 2.0 K, or with correspondingly lower Q's at higher temperatures such as 4.5 K; and (2) advanced fabrication methods for SRF cavities of various geometries (including elliptical, quarter and half wave resonators) to reduce production costs. Industrial metal forming techniques, especially with large grain or ingot material, have the potential for significant cost reductions by simplifying sub-assemblies – e.g., dumbbells and beam tube – and reducing the number of electron beam welds.

Grant applications also are sought to develop (1) improved superconducting materials that have lower RF losses, operate at higher temperatures, and/or have higher RF critical fields than sheet niobium; and (2) techniques to create a layer of niobium on the interior of a copper elliptical cavity, such as by energetic ion deposition, so that the resulting 700-1500 MHz structures have

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Q_0>8 x 10^9 at 2 K. Approaches of interest involving atomic layer deposition (ALD) synthesis should identify appropriate precursors and create high quality Nb, NbN, Nb_3Sn, or MgB_2 films with anti-diffusion dielectric overlayers.

Grant applications also are sought for laser or electron beam surface glazing of niobium for surface purification and annealing in vacuum.

Finally, grant applications are sought to develop advanced techniques for surface processing of superconducting resonators, including methods for electropolishing, high temperature treatments, and surface coatings that enhance or stabilize performance parameters. Methods which avoid use of hydrofluoric acid are desirable. Surface conditioning processes of interest should (1) yield microscopically smooth (R_q< 10 nm / 10µm^2), crystallographically clean bulk niobium surfaces; and/or (2) reliably remove essentially all surface particulate contaminates (> 0.1 µm) from interior surfaces of typical RF accelerating structures. Grant applications aimed at design solutions that enable integrated cavity processing with tight process quality control are highly sought.

For questions related to items (1) through (7) in the first paragraph of this subtopic, contact Dr. Robert Rimmer at Thomas Jefferson Laboratory (rarimmer@jlab.org). For all other questions, contact Dr. Charles Reece at Thomas Jefferson Laboratory (reece@jlab.org).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44b. Radio Frequency Power Sources

Grant applications are sought to develop designs, computer-modeling, and hardware for 5-20 kW continuous wave (cw) power sources at distinct frequencies in the range of 50-1500 MHz, and for 1 MW cw RF power sources at 704 MHz. Examples of candidate technologies include: solid-state devices, multi-cavity klystrons, Inductive-Output Tubes (IOTs), or hybrids of those technologies. Grant applications also are sought to develop computer software for the design or modeling of any of these devices; such software should be able to faithfully model the complex shapes with full self-consistency. Software that integrates multiple effects, such as electromagnetic and wall heating is of particular interest. For questions or further specifications, contact Dr. Leigh Harwood at Thomas Jefferson Laboratory (harwood@jlab.org), Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov), or Dr. Jerry Nolen at Argonne National Laboratory (nolen@anl.gov).

Grant applications also are sought for a microwave power device, klystron, IOT or tunable/phase stabilized magnetron, offering improved efficiency (>55-60%) while delivering up to 8 kW CW at 1497 MHz. The device must provide a high degree of backwards compatibility, both in size and voltage requirements, to allow its use as a replacement for the klystron (model VKL7811) presently used at Thomas Jefferson Laboratory, while providing significant energy savings. For more detail, contact Rick Nelson at Thomas Jefferson Laboratory (nelson@jlab.org).

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Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44c. Design and Operation of Radio Frequency Beam Acceleration Systems

Grant applications are sought for the design, fabrication, and operation of radio frequency accelerating structures and systems for electrons, protons, and light- and heavy-ion particle accelerators. Areas of interest include (1) continuous wave (cw) structures, both superconducting and non-superconducting, for the acceleration of beams in the velocity regime between 0.001 and 0.03 times the velocity of light, and with charge-to-mass ratios between 1/6 and 1/240; (2) superconducting RF accelerating structures appropriate for rare isotope beam accelerator drivers, for particles with speeds in the range of 0.02-0.8 times the speed of light; (3) innovative techniques for field control of ion acceleration structures (1º or less of phase and 0.1% amplitude) and electron acceleration structures (0.1º of phase and 0.01% amplitude) in the presence of 10-100 Hz variations of the structures' resonant frequencies (0.1-1.5 GHz); (4) multi-cell, superconducting, 0.5-1.5 GHz accelerating structures that have sufficient higher-order mode damping, for use in energy-recovering linac-based devices with ~1 A of electron beam; (5) methods for preserving beam quality by damping beam-break-up effects in the presence of otherwise unacceptably-large, higher-order cavity modes – one example of which would be a very high bandwidth feedback system; (6) development of tunable superconducting RF cavities for acceleration and/or storage of relativistic heavy ions; and (7) development of rapidly tunable RF systems for applications such as non-scaling fixed-field alternating gradient accelerators (FFAG) and rapid cycling synchrotrons, either for providing high power proton beams or for proton therapy.

Grant applications also are sought to develop software for the design and modeling of the above systems. Desired modeling capabilities include (1) charged particle dynamics in complex shapes, including energy recovery analysis; (2) the incorporation of complex fine structures, such as higher order mode dampers; (3) the computation of particle- and field-induced heat loads on walls; (4) the incorporation of experimentally measured 3-D charge and bunch distributions; and (5) and the simulation of the electron cloud effect and its suppression. For questions related to software design and modeling, contact Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov).

A high-integrated-voltage SRF cw crab crossing cavity is also of interest. Therefore, grant applications are sought for (1) designs, computer-modeling, and hardware development for an SRF crab crossing cavity with 0.5 to 1.5 GHz frequency and 20 to 50 MV integrated voltage; and (2) beam dynamics simulations of an interaction region with crab crossing. One example of candidate technologies would be a multi-cell SRF deflecting cavity. For questions or further specifications, contact Drs. Yaroslav Derbenev, Geoffrey Krafft or Yuhong Zhang at Thomas Jefferson Laboratory (derbenev@jlab.org, krafft@jlab.org, yzhang@jlab.org). For questions related to multicell SRF deflecting cavities, Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov) also may be contacted.

Grant applications also are sought to develop Hi-B solenoids with minimum fringe field – using 9 T solenoids in the same cryo module of a SRF accelerator as niobium cavities requires the external fringe fields to be very low. The problem is complicated by the inclusion of dipole correction coils and limited space, and the reduced field must be small in multiple directions.

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The development of cost-effective, compact units would make cryo module production simpler and cost effective. For questions, contact Dr. Al Zeller, NSCL/MSU (zeller@nscl.msu.edu).

Finally, grant applications also are sought to develop and demonstrate low level RF system control algorithms or control hardware that provide a robust and adaptive environment suitable for any accelerator RF system. Of special interest are approaches that address the particular challenges of superconducting RF systems, but room temperature systems are of interest as well.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44d. Particle Beam Sources and Techniques

Grant applications are sought to develop (1) particle beam ion sources with improved intensity, emittance, and range of species; (2) methods and/or devices for reducing the emittance of relativistic ion beams – such as coherent electron cooling, and electron or optical-stochastic cooling; (3) methods and devices to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers, electron-beam ionizers, or special stripping techniques); (4) techniques for *in situ* beam pipe surface coating to reduce the ohmic resistance and/or secondary electron yield; and (5) high brightness electron beam sources utilizing continuous wave (cw) superconducting RF cavities with integral photocathodes operating at high acceleration gradients. For questions on ion sources contact Dr. Anatoli Zelenski at Brookhaven National Laboratory (zelenski@bnl.gov).

Accelerator techniques for medium energy rings with high space charge are also of interest. Therefore, grant applications are sought to develop methods for maintaining low 4-D emittance in low and medium energy proton rings (10-30 GeV) with high space charge. Approaches of interest could include, but are not limited to, (1) novel magnet lattices designs, (2) advanced beam injection and ejection schemes, and (3) advanced studies on ring impedance and its reduction. Interested parties should contact Drs. Yaroslav Derbenev, Geoffrey Krafft or Yuhong Zhang at Thomas Jefferson Laboratory (derbenev@jlab.org, krafft@jlab.org, yzhang@jlab.org), for further specifications.

Accelerator techniques for energy recovery linac ERL based electron beam cooling are of high interest for next generation colliders for nuclear physics experiments**.** Therefore, grant applications are sought to develop (1) designs, computer-modeling, and hardware for a fast beam-switching kicker with 0.5 ns duration and 10 to 20 kW power in the range of 5-50 MHz repetition rate; and (2) optics designs and tracking simulations of beam systems for energy recovery linacs and electron circulator rings, with energy range from 5 to 130 MeV. Examples of candidate technologies include SRF deflecting cavity, pulse compression techniques, and beam-based kicker. Grant applications also are sought to develop computer software for the design, modeling and simulating any of these devices and beam transport systems. For questions and further specifications, contact Drs. Yaroslav Derbenev, Geoffrey Krafft or Yuhong Zhang at Thomas Jefferson Laboratory (derbenev@jlab.org, krafft@jlab.org, yzhang@jlab.org). For further information related to coherent electron cooling, please contact Dr. Vladimir Litvinenko at Brookhaven National Laboratory (vl@bnl.gov)

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Lastly, grant applications are sought to develop software that adds significantly to the state-of-the-art in the simulation of beam physics. Areas of interest include (1) intra-beam scattering, (2) spin dynamics, (3) polarized beam generation including modeling of cathode geometries for high current polarized electron sources, (4) electron cooling, beam dynamics, transport and instabilities; and (5) electron or plasma discharge in vacuum under the influence of charged beams. The software should use modern best practices for software design, should run on multiple platforms, and should run in both serial and parallel configurations. Grant applications also are sought to develop graphical user interfaces for problem definition and setup.

For questions, contact Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44e. Polarized Beam Sources and Polarimeters

With respect to polarizing sources, grant applications are sought to develop (1) polarized hydrogen and deuterium (H-/D-) sources with polarization above 90%; (2) cw polarized electron sources delivering beams of ~10 mA, with longitudinal polarization greater than 80%; (3) ~28 MHz cw polarized sources delivering beams of ~500 mA, with polarization greater than 80%; and (4) devices, systems, and sub-systems for producing high current (>200µA), variable-helicity beams of electrons with polarizations greater than 80%, and which have very small helicity-correlated changes in beam intensity, position, angle, and emittance.

For questions on polarized electron sources, contact Dr. Matthew Poelker at Thomas Jefferson Laboratory (poelker@jlab.org). For questions on polarized ion sources contact Dr. Anatoli Zelenski at Brookhaven National Laboratory (Zelenski@bnl.gov).

Grant applications also are sought to develop (1) methods to improve high voltage stand-off and reduce field emission from high voltage electrodes, compatible with ultra-high-vacuum environments; (2) wavelength-tunable (700 to 850 nm) mode-locked lasers, with pulse repetition rate between 0.5 and 3 GHz and average output power >10 W; (3) a high-average-power (~100 W), green laser light source, with a RF-pulse repetition rate in the range of 0.5 to 3 GHz, for synchronous photoinjection of GaAs photoemission guns; and (4) a cost-effective means to obtain and measure vacuum below 10^{-12} Torre.

Grant applications also are sought for (1) advanced software and hardware to facilitate the manipulation and optimized control of the spin of polarized beams; (2) advanced beam diagnostic concepts, including new beam polarimeters and fast reversal of the spin of stored, polarized beams; (3) novel concepts for producing polarizing particles of interest to nuclear physics research, including electrons, positrons, protons, deuterons, and ^3He; and (4) credible sophisticated computer software for tracking the spin of polarized particles in storage rings and colliders.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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44f. Rare Isotope Beam Production Technology
Grant applications are sought to develop (1) ion sources for radioactive beams, (2) techniques for secondary radioactive beam collection, charge equilibration, and cooling; (3) technology for stopping energetic radioactive ions in helium gas and extracting them efficiently as high-quality low-energy ion beams; and (4) advanced parallel-computing simulation techniques for the optimization of both normal- and super-conducting accelerating structures for the future rare isotope facility.

Grant applications also are sought to develop radiofrequency devices for ion transport along surfaces. The transport of ions along walls of gas-filled vacuum chambers by means of a series of electrodes, to which radiofrequency voltages are applied, has gained significant importance, not only in nuclear physics for the stopping and thermalization of rare isotope beams but also in ion chemistry. Ultra-high vacuum compatible large-size printed circuit boards, or similar approaches, together with tailored RF circuitry, are considered most promising for providing low-maintenance reliable performance.

Interested parties should contact Dr. Georg Bollen, FRIB/MSU (bollen@frib.msu.edu).

Grant applications also are sought to develop fast-release solid catcher materials. The stopping of high-energy (>MeV/u) heavy-ion reaction products in solid catchers is interesting for realizing high-intensity low-energy beams of certain elements and for the parasitic use of rare isotopes produced by projectile fragmentation. The development of suitable high-temperature materials to achieve fast release of the stopped rare isotopes as atomic or single-species molecular vapor is required.

Interested parties should contact Dave Morrissey, NSCL/MSU (morrissey@nscl.msu.edu).

Grant applications also are sought to develop techniques for efficient rare isotope extraction from water. Water-filled beam dumps, considered in the context of high-power rare isotope beam production, could provide a source for the harvesting heavy-ion reaction products stopped in the water.

In the case of interest contact Dr. Dave Morrissey, NSCL/MSU (morrissey@nscl.msu.edu).

Lastly, grant applications are sought to develop advanced and innovative approaches to the construction of large aperture superconducting and/or room temperature magnets, for use in fragment separators and magnetic spectrographs at rare isotope beam accelerator facilities. Grant applications also are sought for special designs that are applicable for use in high radiation areas. (Additional needs for high-radiation applications can be found in subtopic "d" of Topic 44, Nuclear Physics Detection Systems, Instrumentation and Techniques.)

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44g. Accelerator Control and Diagnostics
Grant applications are sought to develop (1) advanced beam diagnostics concepts and devices that provide high speed computer-compatible measurement and monitoring of particle beam

intensity, position, emittance, polarization, luminosity, momentum profile, time of arrival, and energy (including such advanced methods as neural networks or expert systems, and techniques that are nondestructive to the beams being monitored); (2) beam diagnostic devices that have increased sensitivities through the use of superconducting components (for example, filters based on high T_c superconducting technology or Superconducting Quantum Interference Devices); (3) measurement devices/systems for cw beam currents in the range 0.1 to 100 μA, with very high precision ($<10^{-4}$) and short integration times; (4) beam diagnostics for ion beams with intensities less than 10^7 nuclei/second; (5) non-destructive beam diagnostics for stored proton/ion beams, such as at the RHIC, and/or for 100 mA class electron beams; (6) devices/systems that measure the emittance of intense (>100kW) cw ion beams, such as those expected at a future rare isotope beam facility; (7) beam halo monitor systems for ion beams; and (8) instrumentation for electron cloud effect diagnostics and suppression.

Grant applications are sought for the development of triggerable, high speed optical and/or IR cameras, with associated frame grabbers of high memory capacity for investigating time dependent phenomena in accelerator beams. Equipment needs to operate in a high-radiation environment, needs to have memory capacity at the level of 1000 frames, and have a frame capture rate of 1 MHz. The cameras will be used for high-speed analysis of optical transition or optical diffraction radiation data. Interested parties should contact Geoffrey Krafft at Thomas Jefferson Laboratory (krafft@jlab.org).

Grant applications also 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. Areas of interest include the development of (1) generic solutions to problems with respect to the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning; (2) systems for predicting insipient failure of accelerator components, through the monitoring/cataloging/scanning of real-time or logged signals; and (3) devices that can perform direct 12-14 bit digitization of signals at 0.5-2 GHz and that have bandwidths of 100+ kHz.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44h. Novel Acceleration Methods for Ions

Grant applications are sought to develop laser radiation pressure driven proton and ion beams sources and accelerators of high-brightness and good repetition rate.

For questions, contact Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

44i. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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45. NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

The Office of Nuclear Physics is interested in supporting projects that may lead to advances in detection systems, instrumentation, and techniques for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art at universities and national user facilities, including the Argonne Tandem Linac System (ATLAS) at Argonne National Laboratory and Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). In addition, a new suite of next-generation detectors will be needed for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade of at the Thomas Jefferson National Accelerator Facility (TJNAF), a future facility for rare isotope beams (FRIB) at Michigan State University, other radioactive beam facilities being developed globally, the underground laboratory proposed by the National Science Foundation, DUSEL, the ongoing luminosity upgrade at the Relativistic Heavy Ion Collider (RHIC), and a possible future electron-ion collider. Also of interest is technology related to future experiments in fundamental symmetries, such as neutrinoless double-beta decay experiments and the measurement of the electric dipole moment of the neutron, where extremely low background and low count rate particle detections are essential. This topic seeks state-of-the-art targets for applications ranging from spin polarized and unpolarized nuclear physics experiments to stripper and production targets required at high-power, advanced, rare isotope beam facilities. Lastly, this topic seeks new and improved techniques and instrumentation to cope with the anticipated high radiation environment for FRIB. All grant applications must explicitly show relevance to the nuclear physics program.

Grant applications are sought in the following subtopics:

45a. Advances in Detector and Spectrometer Technology

Nuclear physics research has a need for devices to detect, analyze, and track charged particles, and neutral particles such as neutrons, neutrinos, photons, and single atoms. Grant applications are sought to develop (1) photosensitive devices such as avalanche photodiodes, hybrid photomultiplier devices, single and multiple anode photomultiplier tubes, silicon-based photomultipliers, high-intensity (~10^{20} γ/s) gamma-ray current-readout detectors (e.g., Compton Diodes), photodiodes for operation at liquid helium temperatures with a signal-to-noise ratio comparable to a photomultiplier tube, photomultiplier tubes designed to work in a liquid helium environment, and other novel photon detectors; (2) detectors utilizing photocathodes for Cherenkov and ultra-violet (UV) light detection, and new types of large-area photo-emissive materials such as solid, liquid, or gas photocathodes; (3) liquid argon and xenon ionization chambers and other cryogenic detectors; (4) single-atom detectors using laser techniques and electromagnetic traps; (5) particle polarization detectors; (6) electromagnetic and hadronic calorimeters, including high energy neutron detectors; and (7) systems for detecting the magnetization of polarized nuclei in a magnetic field (e.g., Superconducting Quantum Interference Devices (SQUIDs) or cells with paramagnetic atoms that employ large pickup loops to surround the sample).

With respect to particle identification detectors, grant applications are sought for the development of: (1) cost-effective, large-area, high-quality Cherenkov materials; (2) cost-effective, position sensitive, large-sized photon detection devices for Cherenkov counters; (3) high resolution time-of-flight detectors; (4) affordable methods for the production of large volumes of xenon and krypton gas (which would contribute to the development of transition radiation detectors and also would have many applications in X-ray detectors); (5) very high resolution particle detectors or bolometers (including the required thermistors) based on semiconductor materials and cryogenic techniques;. Of particular interest are detector technologies capable of measuring energies of alpha particles and protons with less than 5 keV resolution, thereby allowing spectroscopy experiments using light charged particles to be performed in the same way as spectroscopy experiments using gammas.

In addition, grant applications are sought to develop devices designed to perform precision calibration of the detectors listed above. Such devices include novel, controllable calibration sources for electrons, gammas, alphas, and neutrons; pulsed calibration sources for neutrons, gammas, and electrons; precision charged particle beams; and pulsed UV optical sources.

Grant applications also are sought for the development of tilted solenoids for spectrometers. In high field devices, iron has the undesirable property that saturation effects change the field characteristics as a function of induction. However, without iron, the stray fields are very often unacceptably high. For superconducting solenoids this problem can be solved by active shielding. The development of magnet systems with tilted crossed solenoid windings and active shielding could provide a solution for a broad variety of ironless superconducting dipoles, which, for example, could be used in high-acceptance spectrometers like the ISLA spectrometer planned for FRIB. Interested parties should contact Dr. Daniel Bazin, NSCL/MSU (bazin@nscl.msu.edu).

Finally, grant applications are sought for innovative designs of high-resolution particle separators needed for a spectrometer research programs associated with next-generation rare isotope beam facilities. Interested parties should contact Dr. J. A. Nolen, Jr. at Argonne National Laboratory (nolen@anl.gov).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45b. Position Sensitive Charge Particle and Gamma Ray Tracking Devices

Nuclear physics research has a need for devices to track charged particles, and neutral particles such as neutrons, neutrinos, photons, and single atoms. Grant applications are sought to develop advancements in the technology of solid-state tracking devices such as highly-segmented coaxial and planar germanium detectors; silicon drift, strip, and pixel detectors; and silicon 3D devices. With respect to solid state tracking devices, approaches of interest include (1) manufacturing techniques, including interconnection technologies for high granularity, high resolution, light-weight, and radiation-hard solid state devices; (2) highly arrayed solid state detectors for neutron detection, with integrated electronics to read-out pulse height; (3) thicker (more than 1.5 mm) segmented silicon charged-particle and x-ray detectors and associated high density, high resolution electronics; (4) cost-effective production of n-type and p-type silicon drift chambers with active areas greater than 16 cm^2; (5) novel, low-noise cooling devices for efficiently operating these silicon drift chambers; (6) and other solid state detectors described in (2)-(4); and (7) techniques for substantial cost reduction of large-mass Ge detectors.

Grant applications also are sought to develop micro-channel plates; and gas-filled tracking detectors such as proportional, drift, streamer, microstrip, Gas Electron Multipliers (GEMs), Micromegas and other types of micropattern detectors, straw drift tube detectors. For straw tube detectors grant applications are sought for automated assembly and wiring techniques. Interested parties should contact Dr. Bernd Surrow (surrow@mit.edu).

Grant applications also are sought to develop position-sensitive charged particle and photon tracking devices, as well as associated technology for these devices, including (1) position-sensitive, high-resolution germanium detectors capable of determining the position (to within a few millimeters utilizing pulse shape analysis) and energy of individual interactions of gamma-rays (with energies up to several MeV), hence allowing for the reconstruction of the energy and path of individual gamma-rays using tracking techniques; (2) hardware and software needed for digital signal processing and gamma-ray tracking – of particular interest is the development of efficient and fast algorithms for signal decomposition and improved tracking programs; High speed triggers using FPGA's capable of decision making in less than 1 us; (3) alternative materials, with comparable resolution to germanium, but with significantly higher efficiency and relatively higher temperature operation (in order to overcome the costly and bulky requirement to cool germanium detectors to liquid nitrogen temperatures); (4) improvements and new developments in micropattern detectors – this would specifically include commercial and cost effective production of GEM foils and other types of micropattern structures, such as fine meshes used in Micromegas, as well as novel approaches that could provide high-resolution multidimensional readout; (5) advances in more conventional charged-particle tracking detector systems, such as drift chambers, pad chambers, time expansion chambers, and time projection chambers (areas of interest include improved gases or gas additives that resist aging, improve detector resolution, decrease flammability, and offer larger/more uniform drift velocity); (6) high-resolution, gas-filled, time-projection chambers employing CCD cameras to perform an optical readout; (7) gamma-ray detectors capable of making accurate measurements of high intensities (>10^{11} /s) with a precision of 1-2 %, as well as economical gamma-ray beam-profile monitors; (8) for rare isotope beams, next-generation, high-spatial-resolution focal plane detectors for magnetic spectrographs and recoil separators, for use with heavy ions in the energy range from less than 1 MeV/u to over 100 MeV/u; (9) a bolometer with high-Z material (e.g., W, Ta, Pb) for gamma ray detection with segmentation, capable of handling 100 -1000 gamma rays per second; (10) detectors made of more conventional materials (silicon or scintillator), capable of reconstructing multiple-Compton gamma-ray scattering with mm resolution; and (11) advances in CCD technology, particularly in areas of fast parallel, low-power readout, and cross-talk control. In the context of (4) we are developing large area imaging devices using the Micromegas technology associated with the read-out of a high number of channels (typically ~10,000) we will need to develop PCB boards that have an extremely good surface finish (in the sub-micron domain), in order to get minimize gain fluctuations and sparking. Interested parties should contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu).

Finally, grant applications are sought to develop high-rate, position sensitive beam detectors and timing detectors for high-energy heavy-ions, (for example diamond detectors), including the development of multi-channel readout electronics for fast high-rate detectors. Future rare isotope beam facilities like FRIB will provide beams with unprecedented intensity, creating a challenge for single particle tracking and beam profile measurements. The development of position sensitive fast particle detectors for particle tracking/timing and direct/indirect beam profile measurement techniques with high rate capability would be desirable. Ideally these detectors would provide both position and timing measurements and be radiation resistant. Interested parties should contact Dr. Marc Hausmann, NSCL/MSU (Hausmann@nscl.msu.edu).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45c. Technology for Rare Particle Detection

Grant applications are sought for particle detectors and techniques that are capable of measuring very weak, very rare event signals in the presence of significant backgrounds. Such detector technologies and analysis techniques are required in searches for rare events (such as double beta decay) and for applications in extending our knowledge of new nuclear isotopes produced at radioactive beam facilities. Rare decay and rare phenomenon detectors require large quantities of very clean materials, such as clean shielding materials and clean target materials. For example, neutrino detectors need very large quantities of ultra-clean water.

Grant applications are sought to develop (1) ultra-low background techniques of contacting, supporting, cooling, cabling, and connecting high-density arrays of detectors – ultrapure materials must be used in order to keep the generated background rates as low as possible (goal is 1 micro-Becquerel per kg); (2) advanced detector cooling techniques and associated

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infrastructure components (high-density signal cabling, signal and high voltage interconnects, vacuum feedthroughs, front-end amplifier FET assemblies), in order to assure ultra-low levels of radioactive contaminants; (3) measurement methods for the contaminant level of the ultra-clean materials; (4) novel methods capable of distinguishing between gammas and charged particles; and (5) methods by which the backgrounds to rare searches, such as those induced by cosmogenic neutrons, can be tagged, reduced, or removed entirely.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45d. Large Band Gap Semiconductors, New Bright Scintillators, Calorimeters, and Optical Elements

Nuclear physics research has a need for developing cost effective new detector and scintillation material with high light outputs and shorter decay times relative to NaI and CsI for manufacturing practical devices to detect charge particles and gamma rays. Therefore, grant applications are sought to develop new materials or advancements for photon detection, including (1) large band gap semiconductors such as CdZnTe, HgI_2, AlSb, etc.; (2) bright, fast scintillator materials ($LaHA_3$:Ce, where HA=Halide) and scintillators with pulse-shape discrimination (PSD) (n/gamma and charged particle); (3) selenium based detectors (perhaps using GaSe, CdSe or ZnSe); (4) plastic scintillators, fibers, and wavelength shifters; (5) cryogenic scintillation detectors (LXe); (6) Cherenkov radiator materials with indices of refraction up to 1.10 or greater, and with good optical transparency; and (7) new and innovative calorimeter concepts, including new materials, higher packing densities, or innovative fiber and absorber packing schemes.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45e. Specialized Targets for Nuclear Physics Research

Grant applications are sought to develop specialized targets for the nuclear physics program, including (1) polarized (with nuclear spins aligned) high-density gas or solid targets; (2) frozen-spin active (scintillating) targets; (3) windowless gas targets and supersonic jet targets for use with very low energy charged particle beams; (4) liquid, gaseous, and solid targets capable of high power dissipation when high intensity, low-emittance charged-particle beams are used; and (7) very thin windows for gaseous detectors, in order to allow the measurement of low energy ions.

Grant applications also are sought to develop the technologies and sub-systems for the targets required at high-power, rare isotope beam facilities that use heavy ion drivers for rare isotope production. Targets for heavy ion fragmentation and in-flight separation are required that are made of low-Z materials and that can withstand very high power densities and are tolerant to radiation. Interested parties should contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu).

Also required are targets that would be used with high-power light ion beams for the production of exotic isotopes by spallation reactions.

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Finally, grant applications are sought to develop techniques for (1) the production of ultra-thin films needed for targets, strippers, and detector windows – regarding next generation rare isotope beam facility, there is a need for stripper foils or films (in the thickness range from a few micrograms per cm^2 to over 10 milligrams per cm^2) for use in the driver linac, with very high power densities; and (2) the preparation of targets of radioisotopes, with half-lives in the range of hours, to be used off-line in both neutron-induced and charged-particle-induced experiments.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45f. Technology for High Radiation environment of Rare Isotope Beam Facility
The establishment of next generation rare isotope beam facilities requires new and improved techniques, instrumentations and strategies to deal with the anticipated high radiation environment in the production, stripping and transport of ion beams. Therefore grant applications are sought to develop:

(1) Rotating vacuum seals for application in high-radiation environment: Vacuum rotary feedthroughs for high rotational speeds, which have a long lifetime under a high-radiation environment, are highly desirable for the realization of rotating targets and beam dumps for rare isotope beam production and beam strippers in high-power heavy-ion accelerators. Interested parties should contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu).

(2) Radiation resistant multiple-use vacuum seals: Elastomer-based multi-use vacuum seals have a limited lifetime due to radiation damage in the high-radiation environment found in the target facility of FRIB and other high-power target facilities. Alternative solutions that provide extended lifetimes and are suitable for remote-handling applications are needed. Interest parties should contact Tom Burgess, NSTD/ORNL (burgesstw@ornl.gov).

(3) Radiation resistant magnetic field probes based on new technologies: An issue in all high-power target facilities and accelerators is the limited lifetime of conventional nuclear magnetic resonance probes in high-radiation environments. The development of radiation-resistant magnetic field probes (possibly based on new techniques like ion traps) for 0.2-5 Tesla and a precision of $dB/B<1E-4$ would be highly desirable. Interested parties should contact Dr. Georg Bollen, FRIB/MSU (bollen@frib.msu.edu).

(4) Techniques to study radiation transport in beam production systems: The use of energetic and high-power heavy ion beams at future research facilities will create significant radiation fields. Radiation transport studies are needed to design and operate facilities efficiently and safely. Further improvements to radiation transport codes and models of secondary radiation production, shielding, and heat deposition – along with their validation against experimental data – are necessary. Heavy ion transport calculations in general take significantly longer computational time than for light ion transport. Therefore, improvements in calculation efficiencies are needed. Currently available heavy ion transport codes do not account for the production and intensity of the ions, or for changes in charge-state distributions as the ions pass through matter or magnetic fields. The development and incorporation of charge-state distribution models into radiation transport codes would enhance both the design of beam stripping and beam absorption components and the safety and lifetime consequences of

produced radiation fields. Interested parties should contact Dr. Reg Ronningen, NSCL/MSU (ronningen@nscl.msu.edu).

(5) Techniques for modeling radiation damage with heavy ions: The use of energetic and high-power heavy ion beams at future research facilities will create significant levels of radiation damage to facility components, thus limiting their useful lifetimes. Sparse experimental data taken at low energies indicate that the radiation damage caused by heavy ions may be orders of magnitude higher than that predicted by existing models, such as those currently implemented in radiation transport codes. It is purported that phenomena such as the Swift Heavy Ion effect, which are not accounted for, may be important. New and/or improved models are needed to reliably estimate the effects of radiation damage by heavy ions, in order to better design and optimize the performance of future facilities. Interested parties should contact Dr. Reg Ronningen, NSCL/MSU (ronningen@nscl.msu.edu).

(6) Techniques for thermal studies of targets, beam absorbers, strippers: High intensities of heavy ion beams for rare isotope beam production will result in a significant energy density deposited in facility components such as production targets, beam absorbers, and beam strippers. The anticipated levels of energy density will require sophisticated designs for these components, in order to ensure the integrity and operability for extended periods of time. Efforts are needed to calculate energy deposition and to perform thermal and stress analyses. Interested parties should contact Dr. Reg Ronningen, NSCL/MSU (ronningen@nscl.msu.edu).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

45g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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46. NUCLEAR PHYSICS ISOTOPE SCIENCE AND TECHNOLOGY

Stable and radioactive isotopes are critical to serve the broad needs of our modern society and are critical to scientific research in chemistry, physics, energy, environment, material sciences and for a variety of applications in industry and national security. A primary goal of the Department of Energy's Isotope Development and Production for Research and Applications Program (Isotope Program) within the Office of Nuclear Physics (NP) is to support research and development of methods and technologies in support of the production of isotopes used for research and applications that fall within the Isotope Program portfolio. The Isotope

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Program produces isotopes that are in short supply in the U.S. and of which there exists no domestic commercial production capability; some exceptions include special nuclear materials and molybdenum-99, for which the National Nuclear Security Administration has responsibility. The benefit of a viable research and development program includes an increased portfolio of isotope products, more cost-effective and efficient production technologies, a more reliable supply of isotopes year-around and the reduced dependence of foreign supplies. With the successful development of advanced production technologies more isotopes can be produced and distributed for research and applications. Additional guidance for research isotope priorities is provided in the Nuclear Science Advisory Committee Isotopes (NSACI) report available at (http://www.sc.doe.gov/np/nsac/nsac.html). Priorities for research isotope production are articulated in this report which will serve to guide production plans of the Isotope Program.

Grant applications are sought in the following subtopics:

46a. Novel or Improved Production Techniques for Radioisotopes or Stable Isotopes

Research should focus on the development of advanced, cost-effective and efficient technologies for producing isotopes that are in short supply and that are needed by the research and applied communities. The successful research grants should lead to breakthroughs that will facilitate an increased supply of isotopes that complement the existing portfolio of isotopes produced and distributed by the Isotope Program.

Grant applications are sought for new technologies to produce large quantities of separated isotopes – such as kg quantities of Germanium-76 (^{76}Ge), Selenum-82 (^{82}Se), Tellurium-130 (^{130}Te), Xenon-136 (^{136}Xe) – and other materials that are needed for rare particle and rare decay experiments in nuclear physics research. Further guidance for research isotope priorities is provided in the Nuclear Science Advisory Committee Isotopes (NSACI) report available at (http://www.sc.doe.gov/np/nsac/nsac.html).

Interested parties may contact Wolfgang Runde at runde@lanl.gov.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

46b. Improved Radiochemical Separation Methods for Preparing High-Purity Radioisotopes

Separation of isotopes from contaminants and bulk material and the purification of the isotope to customer specifications is a critical process in the production cycle of an isotope. Most processes developed to date rely on old technologies and still require extensive workforce to operate specialized equipment, such as manipulators for remote handling in hot cell environments. Conventional separation methods may include liquid-liquid extraction, column extraction, distillation or precipitation and are used to separate radioactive and non-radioactive trace metals from target materials, lanthanides, alkaline and alkaline earth metals, halogens, or organic materials. High-purity isotope products are essential for high-yield protein radiolabeling, for radiopharmaceutical use, or to replace materials with undesirable radioactive emissions. Improved radiochemical separation methods can be achieved and costs of isotope production can be reduced by a) improvements in separations chemistry methods, and b) implementing automated systems and robotics. Of particular interest are developments that automate routine

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separation processes in order to reduce operator labor hours and worker radiation dose, including semi-automation modules for separations or automated, micro-processor controlled systems for elution, radiolabeling, purification, and dispensing.

Applications are sought for innovative developments and advances in separation technologies to reduce processing time, to improve separations efficiencies, to automate separation systems, to minimize waste streams, and to develop advanced materials for high-purity radiochemical separations. In particular, the Department seeks improvements in (1) lanthanide and actinide separations, (2) in the development of higher binding capacity resins and adsorbents for radioisotope separations to decrease void volume and to increase activity concentrations, (3) the scale-up of separation methods demonstrated on a small scale to large-volume production level, and (4) new resin and adsorbent materials with increased resistance to radiation.

The following are some examples for advanced chemical separation technology needs. In lanthanide radiochemistry, improvements are sought to a) prepare high-purity samarium-153 by removing contaminant promethium and europium; or b) to prepare high-purity gadolinium-148 and gadolinium-153 by ultra-pure separation from europium, samarium, and promethium contaminants. In actinide radiochemistry, innovative methods are sought a) to improve radiochemical separations of or lower-cost approaches for producing high-purity actinium-225 and actinium-227 from contaminant metals, including thorium, radium, lead, and/or bismuth; or b) to improve ion-exchange column materials needed for generating lead-212 from radium-224, and bismuth-213 from actinium-225 or radium-225. The new technologies must be applicable in extreme radiation fields that are characteristic of chemical processing involving high levels of alpha-and/or beta-/gamma-emitting radionuclides.

Interested parties May contact Dr. Russ Knapp (knappffjr@ornl.gov).

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

46c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Manouchehr Farkhondeh, 301-903-4398, manouchehr.farkhondeh@science.doe.gov

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47. DEACTIVATION AND DECOMMISSIONING

The need to reduce risks to workers from potential exposures associated with decontamination and decommissioning activities. Workers are required to wear personnel protective equipment to protect them from exposure to hazardous contaminants, such as radionuclides, metals such as mercury, lead, asbestos, and organics. The DOE is interested in new or improved personnel protective clothing or equipment that not only is protective against the contaminants but also is waterproof. The needs to decontaminate and dispose of hundreds of miles of contaminated piping, during both site remediation and D&D activities. In particular, the DOE is interested in the development of technology to shred contaminated piping and systems and to separate metallic and non-metallic materials, while also ensuring the protection of workers and the environment.

Process piping used in the production of nuclear materials contains residual radionuclide that must be removed during the faculty decommissioning process. Removal of the residual radioactive material is a necessary part of preparing the piping system components for proper disposal in accordance with Federal, State, and local regulations. Additionally, the subsurface of the interior pipe walls can be activated due to the exposure or absorption of radioactive materials or particles and should be sealed after cleaning to prevent either the release of activated material or recontamination of cleaned surface. The accumulation of corrosion products on the interior pipe walls entraps radioactive particles. Detecting and identifying the radionuclide particles is a prerequisite to prepare the piping system components for proper disposal in accordance with Federal, State, and local regulations.

Effective fixation of contamination and/or protection from recontamination is of critical importance for conducting D&D operations to prevent worker uptake and spread of contamination. The wide variety of contaminants and contaminated surfaces encountered in the DOE D&D program requires a systematic focus on developing suitable weather/solar resistant fixatives that can be easily removed if needed and that can have application across the wide range of combinations of contaminants including radioactive compounds and airborne particles that can become an exposure hazard on a variety of surfaces including concrete, rusted metals and surfaces with flaking paint. Such fixatives are needed to reduce the technical risks and uncertainties during cleanup, decontamination and/or decommissioning projects.

The Department of Energy is faced with the challenge of decommissioning multiple facilities that are highly contaminated and/or structurally unsound. Entry by workers to conduct characterization is therefore hazardous from radiological/chemical exposure, or as a result of structural failure perspectives. A family of analytical tools must be developed and tested to perform quantitative or semiquantitative analyses of materials inside these facilities. Analytical equipment must be capable of operating remotely for extended periods of time and have minimum maintenance requirements requiring physical contact between workers and the instrumentation. The equipment must also be capable of being deployed on robotic platforms which also operate remotely and will transport the instrumentation from location to location. This type of information is required for planning to ensure worker safety during facility decommissioning and for planning for waste disposition.

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Grant applications are sought in the following subtopics:

47a. Develop Fiber Optic Sensor to Detect Ionizing Radiation and Identify the Type of Radionuclide Contamination

Research should be pursued to develop a fiber optic sensor device that can detect and measure the ionizing energy produced by radionuclide formed from residual deposits in process piping systems used in the production of nuclear materials. The fiber optic measurement system should contain signal processing components that can identify the specific radionuclides of the residual deposits and quantify the concentration of the radioactive materials in the pipes. The fiber optic sensor device should be designed to operate in steel and stainless steel pipe & tubing ranging from 6 inches to ¼ inches nominal pipe diameter. Often corrosion deposits and films are encountered on the inside pipe wall surfaces which entrap radioactive particles, therefore, the fiber optic sensor must be able detect and measure radionuclide in this type of environment.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

47b. Develop Piping 'Pig' Using Nanofiber Technology to Decontaminate Internal Piping and Tubing Surfaces

Pigs are internal cleaning devices that travel through a pipe using fluid pressure. The removal of scale is accomplished by scrapping or abrasive action. Research should be pursued to develop a pig that is manufactured using nanofibers to remove residual radioactive deposit from the interior of pipe used in the production of nuclear materials. The nanofiber pig should be capable of removing radioactive deposits with limited abrasion to the interior pipe wall. Additionally, the nanofiber pig should be propelled using a gelled typed fluid to coat the clean surface. This gel coating is to seal the internal pipe surface to prevent recontamination either by subsurface activated material or loose radioactive debris. The nanofiber pig should be capable of cleaning steel and stainless steel pipe and tubing ranging from 6 inches to ¼ inches in nominal diameter. The gel coating should have a cure time range of 12-24 hours.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

47c. Fixatives/Protective Coatings with Easy Application and Removal

Research should be pursued to develop a fixative/sealant product with the ability to be easily applied on a variety of surfaces indoors and outdoors, remain intact for as long as needed and be easily removed if required. This fixative must have the ability to protect and prevent the spread of contamination on a long term basis from a wide range of surfaces from highly porous concrete to weathered surfaces with dust, rust and/or flaking paint and not present additional problems during demolition, i.e. hard to cut and/or loss of adhesion. The fixative must be safe, non-carcinogenic, and resistant to weather/solar conditions (e.g., rain, solar heating and radiation). When necessary, the fixative coating has to have the ability to be easily removed without damage the underlying surfaces. The coating should have the ability to be sprayed by an industrial sprayer or applied by a paint brush or roller. Products of this work will have applicability throughout the DOE complex for all D&D actions, as well as other federal agencies and the commercial nuclear industry.

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Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

47d. Multi-Analyte Sensors for Characterization of Contaminated Facilities—Analysis for RCRA/CERCLA Compounds and Structural Compounds

A need exists for analytical tools that are capable of operating remotely in a hazardous environment that can provide characterization of RCRA constituents with sufficient resolution to plan waste disposal actions and identify chemical hazards that that must be mitigated to ensure worker safety during building entry and/or waste disposition. The ability to specifically characterize materials containing asbestos, beryllium and mercury would be advantageous, while general characterization of the suite of RCRA constituents is required. The ability to operate for extended periods in high radiation environments is essential, while robust construction and operating configuration is essential because minimum contact with workers will be possible once the instrument is deployed in the contaminated facility. A final essential requirement is that the equipment be of sufficiently small size that it can be readily deployed on remotely operated 'vehicles' will be use to navigate within the facility.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

47e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

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48. IN SITU REMEDIATION

Controlling the source of contamination is integral to meeting remedial objectives for mitigating direct exposure to contamination and limiting the flux of contamination to groundwater. Functionally, the methods for addressing subsurface contamination must remove contamination and/or reduce transport of contaminants through the vadose zone. However, this problem is particularly challenging in vadose zone environments, which consist of complex stratified layers of unconsolidated and water-unsaturated sediments that are, in many places, contaminated with radionuclides, metals, organics, and, in some cases, complex mixtures. They serve as a potential source of groundwater contamination and the primary conduit for transport from the ground surface. If contamination is in the deep vadose zone and disperses to associated groundwater, *in situ* remediation technologies or defensible technical data and justification for enhanced attenuation may be the only ways to perform effective remediation; they may provide the only viable paths to long-term stewardship of sites contaminated with metals and long-lived radionuclides other than costly, ineffective and impractical physical removal techniques.

Integral to the successful development of any remedial technology is the ability to monitor, and eventually predict, the delivery, emplacement, and long term performance of the treatment. For example during the injection of a material for remediation (e.g. polysulfide liquid or hydrogen sulfide gas) monitoring wells around the injection wells are monitored for parameters that will indicate the arrival, concentration and distribution of the injected remedial fluid or gas. In general, such monitoring is complicated by subsurface heterogeneity and by the disparity of scales across which hydrological properties span, because these properties control the distribution of the remedial amendment and thus the location of subsequent transformations. Because of their limited spatial extent, these methods often cannot provide sufficient information to describe key controls on subsurface flow and transport. This is especially true in the vadose zone, where vertical infiltration pathways can form as a result of variable saturation and heterogeneity and where fluid recovery for sampling can be challenging. The inability to conventionally characterize controlling properties and induced processes at a high enough spatial resolution, and over a large enough spatial extents, prohibits accurate assessment of remedial actions for deep vadose zone treatments.

Research into new approaches and tools for monitoring the deep vadose zone is needed to develop innovative measurement and monitoring techniques to: 1) measure and verify the emplacement of a remedy, 2) track the movement of contaminants and quantify variations over plume scales, and 3) monitor the long-term effectiveness and stability of the remedy within the deep vadose zone, 4) monitor the progress and distribution of the remediation using alternate subsurface interrogation techniques, including methods that use spatial integrating measures or volumetric measures, and 5) limit future costs of performance monitoring. The ability to monitor the remedy emplacement will allow remediation approaches to be optimized during the application as well as lead to better application methods. Also the ability to verify the remedy performance over time will lead to lower life-cycle costs.

Widespread industrial use of mercury has resulted in significant environmental contamination, with mercury releases impacting soil, sediment, groundwater, and surface water. The behavior of mercury is complex and depends upon factors including its oxidation state and environmental conditions. Parameters such as pH, redox status, and the presence of various minerals and ligands all influence mercury speciation, reactivity, partitioning, and mobility.

A number of treatment options are available for remediating or removing mercury in soil, including soil washing, acid leaching, excavation and disposal, thermal desorption, and stabilization (Otto, 2007). Most of these technologies, with the exception of the last two, are ex situ methods, and they are often associated with high costs, limited applicability, multi-stage processes, and the generation of ancillary waste streams. Cost-effective and technically-sound approaches are needed for in situ remediation of mercury contamination in soil. These methods should provide an interim or permanent alternative to excavation and disposal and should target physical removal of mercury or in-place stabilization. Technologies may be new developments or based upon existing technologies that have been improved with respect to efficiency, applicability, and cost-effectiveness. Research and development may target mercury present in multiple forms but should include efforts to address the remediation of high concentrations of elemental mercury in source zones.

Grant applications are sought in the following subtopics:

48a. Novel Measurement and Monitoring Concepts for Deep Vadose Zone

Enhanced attenuation, remediation, and monitored natural attenuation strategies require innovative measurement and monitoring tools to track performance and/or verify containment measures. The need to monitor the remedy application has been recognized for many years; however, monitoring approaches are still generally limited to monitoring wells. Alternate methods should be developed to monitor the distribution of the remedy, track the movement and property variation of contaminants and co-contaminants over plume scales, and determine the long-term stability of immobilized contaminants in the environment using alternate subsurface interrogation techniques. Methods that use spatial integrating measures or volumetric measures, including geophysics or other volumetric or spatial measurement techniques such as push-pull testing for interrogating the subsurface, are within this scope.

The ability to monitor the remedy emplacement and performance will allow remediation approaches to be optimized during the application, as well as, lead to better selection of appropriate technologies and application methods, and provide an independent validation of transport model predictions. Areas of interest include non-invasive techniques to delineate subsurface structure, track migration of contaminants in the subsurface, detect contaminant flux and evaluate the rate and progression of biogeochemical processes. All proposals should emphasize development of new techniques relevant to the field setting that address crucial measurement needs in support of *in situ* subsurface remediation, in particular – deep vadose zone environments. Coordination with an EM field research sites is required. Field testing of existing prototype monitoring devices or autonomous sampling systems is within the scope. The contaminant of interest for this Applied Research area is technetium-99 as well as nitrate and complexing agents as co-contaminants.

Areas of interest in remedial monitoring include:

- Expand monitoring beyond traditional monitoring wells to include ecosystem monitoring, biomarkers and biological monitoring, boundary condition monitoring (weather, evapotranspiration, etc.).
- New techniques for measuring remedy application considering integrated monitoring techniques (spatial or volumetric measures) such as tracers, geophysics and barometric responses.

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- New strategies and approaches to performance (long-term) monitoring networks based on attributes such as change from baseline (predicted range), indicator parameters that represent a set of properties (e.g., resistivity), and spatially integrated measures (e.g. flux).

Following emplacement of the remedy, data is collected to access its effectiveness. At some point, enough information will have been gathered to verify the remedy as well as establish the baseline for system performance. At this juncture the monitoring focus should transition to a long-term monitoring approach that is based on the strategy of detecting ***change outside the expected range***. When long-term monitoring is directed toward this objective, opportunities for innovation arise. Performance (long-term) monitoring could be more efficient and potentially more effective using a natural systems approach in which larger scale perturbations are monitored and compared to a baseline. A change from the predicted range may warrant further investigation or actions. These new strategies and techniques must be sufficiently developed to make them acceptable to regulators and stakeholders. For example large-scale parameters such as changes in ground cover or vegetation type might signal an increase in precipitation and moisture influx to the vadose zone which will impact a remedy. Monitoring "indicators" and larger-scale effects may be most efficient for long-term monitoring. In developing new approaches to performance monitoring the objectives and desired attributes of a performance monitoring (long-term) monitoring network need to be identified and considered.

- New strategies and approaches to performance (long-term) monitoring networks should be based on the attributes including (after Gilmore et al. 2007):
- Measure change from baseline (predicted range)
- Utilize indicator parameters that represent a set of properties (e.g., resistivity)
- Utilize spatially integrated measures (e.g. flux)
- Measures of ecological health
- Low maintenance
- Low cost
- Robust
- Passive
- Utilize leading (failure) indicators
- Flexible to incorporate new tools

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

48b. In Situ Remediation in Soil

Research and development focused on in situ mercury stabilization in soil should address a number of issues relevant to implementability. First, requirements for appropriate soil characterization must be established, since soil type, mineralogy, mercury speciation, mercury concentration, and co-contaminants will influence the suitability, effectiveness, and required loading of amendments used in the stabilization process (U.S. Environmental Protection Agency, 2007). Second, factors that limit or control treatment depth and the uniformity of amendment delivery must be determined. These factors include the delivery method (e.g., via reactive gas, flowable fill, liquid injection, or other means), soil permeability, and subsurface heterogeneity, for example. Third, the longevity of the stabilization method must be demonstrated for variable environmental conditions. Subsurface redox conditions and pH may change over time, leading to unanticipated leaching of mercury from "stabilized" soils. Weathering and exposure may also result in undesirable mercury release. In situ physical removal of mercury from soil should address similar issues, including the influence of soil characteristics, mercury speciation and concentration, zone of influence for the removal method, and residual mercury levels that can be achieved. Energy requirements should also be established, particularly in the case of thermal technologies.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

48c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

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49. NOVEL MONITORING CONCEPTS

Currently inadequate long-term monitoring and maintenance strategies and technologies are available to verify cleanup performance which could potentially invalidate selected remedies and escalate cleanup costs. This Initiative is aimed at developing and deploying cost-effective long-term strategies and technologies to monitor closure sites (including soil, groundwater and surface water) with multiple contaminants (organics, metals and radionuclides) to verify integrated long-term cleanup performance. Long-term monitoring and maintenance is one of the largest projected cost centers in the overall lifecycle of Environmental Management; moreover, costs associated with the implemented systems will extend into future Legacy Management. Much of the cost is associated with frequent analyses of contaminants in a large number of monitoring wells. Such measurements are expensive and the resulting datasets are inefficient and inadequate for meeting long term monitoring objectives.

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To meet all of the goals, we propose to solicit the best concepts from industry in the following four broad themes.

A. spatially integrated monitoring tools,
B. onsite and field monitoring tools and sensors,
C. engineered diagnostic components, and
D. integrated risk management and decision support tools

Grant applications are sought in the following subtopics:

49a. Spatially Integrated Monitoring Tools
Spatially integrated monitoring tools would focus on documenting plume stability and/or natural attenuation, as well as providing a physical assessment of potential problems (e.g., subsidence in isolated waste). Technologies include meteorological data and satellite imagery (to document boundary conditions, to specifically measure the driving forces for plume migration), permanent geophysical survey system using emplaced electrodes, ecosystem monitoring, push pull methods, and the like.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

49b. Onsite and Field Monitoring Tools and Sensors
Onsite and field monitoring tools and sensors would reduce laboratory analysis costs. Example technologies include field analysis sensors, deployed sensors, screening tools and other concepts to reduce the number of lab-based analyses or to reduce sampling costs (e.g., reduce investigation derived waste). This would also include identification of indicator or surrogate parameters and documentation that such parameters would provide equal or better documentation of environmental protection to concentration measurements.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

49c. Engineered Diagnostic Components
Engineered diagnostic Components are designed to provide a clear indication of system performance. These system components include early warning indicators, easily and inexpensively detected tracers that are added to the waste or facility, systems that control and collect water to a single location, and other similar ideas. Such system components are particularly useful for radioactive wastes where predicted transport times are often 1000s of years and traditional monitoring (down gradient monitoring wells in the groundwater) provide little indication that models and predictions are valid – once a problem is detected, it is too late to perform a cost effective contingency. Engineered diagnostic Components provide opportunities for vadose zone monitoring, gas phase analytes, and more control on the amount of data needed and the costs to collect the data, while simultaneously increasing confidence and sensitivity of the monitoring system.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

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49d. Integrated Risk Management and Decision Support Tools
Integrated risk management and decision support tools facilitate implementation of isolation/monitoring systems and assure that they are both effective and optimized (i.e., reduced cost). This is critical to the overall success and includes technologies for the optimization process (e.g., models), engineering designs of waste isolation that allow/encourage detoxification of the contaminants over time, reasonable contingency plan development, and the like. (in collaboration with WBS element 2.2.2)

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

49e. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contacts: Latrincy Whitehurst, 301-903-7654, Latrincy.Whitehurst@em.doe.gov

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50. REMOTE SENSING

For decades, the Remote Sensing Program has been a cornerstone in the national capability for the detection of facilities and activities related to the proliferation of foreign nuclear programs. The Remote Sensing Program research projects encompass a wide variety of potential capabilities to detect signatures associated with the development of nuclear weapons. The research areas in the Remote Sensing program include sensor development, image processing, and digital signal processing techniques for characterization of observed phenomena.

50a. Improvement in Quality of II-VI and III-V Semiconductor Materials for IR Focal Plane Arrays
The ability to grow defect-free materials could conceivably enhance the performance and reliability of constituent photodiodes in II-VI and III-V infrared imaging focal plane arrays, such as HgCdTe and Sb-based SLS. As in any semiconductor device, elimination of defects and anomalies in the underlying material system will enhance device quality and performance, yielding improved focal plane arrays. Applications are sought to enable refinements in focal plane array technology, systematically and routinely through any relevant strategies, including but not limited to, application of advanced analytical imaging methodologies and evaluation of the impact of defects and anomalies on FPA performance and lifetime. Partnership with II-VI / III-V vendors or National Labs may be desirable to access sample test articles.

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Contact: Victoria Franques, 202-586-2560, victoria.franques@nnsa.doe.gov

50b. Thermal Mitigation for IR Detectors

Applications are sought to develop advanced thermoelectric or other non-vibrational, low-power cooling systems capable of bringing temperatures in a one inch square area producing 5W of heat down from ambient to 77K at high efficiency. The next-generation MWIR and LWIR imaging systems still require cooling of detectors and back focal assemblies to reduce self-emission and improve sensitivity. Current conventional cooling systems (such as Sterling Cycle coolers or refrigerant gases) are bulky and/or introduce additional vibration, heat, and power consumption into the system.

Contact: Victoria Franques, 202-586-2560, victoria.franques@nnsa.doe.gov

50c. Waveguide-Coupled Optical Modulator for W-Band Up-Conversion

Passive millimeter wave imaging provides many advantages in remote sensing, such as the ability to see through clouds, dust, and smoke, as well as daytime/nighttime operation. One atmospheric window that is exploited in millimeter wave imaging is at 94GHz (W-band). However, a potential drawback with passive millimeter wave imaging is its inherent low resolution compared to optical approaches, such as passive infrared imaging. Therefore, at reasonable standoff distances, sub-pixel detection methods, or exploitation of mixed pixel data, become essential. One approach to extracting additional information is the use of millimeter wave polarimetry. However, this approach requires the polarization signals to be combined coherently, which can cause the very sensitive components used in CMB (Waveguide-coupled optical Modulator for W-band) research to suffer significant waveguide loss in signal routing. This drawback can be alleviated by optical up-conversion, while still preserving the amplitude and phase relationship of multiple signals. Moreover, optical up-conversion would provide other benefits: (1) it would enable advances in optical components, which result from the telecomm build-out, to be leveraged; and (2) it would permit remote operation of two or more receivers in a phased array, in order to increase imaging resolution. Unfortunately, no commercial full-band W-band (75-110 GHz) modulators exist presently, although research suggests steady improvement in the fabrication of research devices. Therefore, to advance instrument development in passive millimeter wave imaging for remote sensing applications, grant applications are sought for the design and fabrication of a low-insertion-loss W-band modulator having a mm-wave insertion loss of < 2.5dB and an optical insertion loss of < 3dB.

Contact: Victoria Franques, 202-586-2560, victoria.franques@nnsa.doe.gov

50d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Victoria Franques, 202-586-2560, victoria.franques@nnsa.doe.gov

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51. RADIATION DETECTION

The Office of Nuclear Nonproliferation Research and Development (NA-22) is focused on enabling the development of next generation technical capabilities for radiation detection of nuclear proliferation activities. As such, the office is interested in the development of radiation detection techniques and sensors, and advanced detection materials, that address the detection and isotope identification of unshielded and shielded special nuclear materials, and other radioactive materials in all environments. In responding to these challenging requirements, recent research and development has resulted in the emergence of radiation detection materials that have good energy resolution. From these materials, the development of radiation detectors that are rugged, reliable, low power, and capable of high-confidence radioisotope identification are sought. Currently, the program is focused on the development of improved capabilities for both scintillator- and semiconductor-based radiation detectors. The objective of this topic is to gain insight into a mechanistic understanding of material performance as the base component of radiation detectors. That is, the program is interested in moving beyond the largely empirical approach of discovering and improving detector materials to one based on a clear understanding of basic materials properties.

51a. Scintillators for Gamma Spectroscopy

We would like to support research on materials that will lead to practical high-brightness scintillators with energy resolution significantly better than the currently available sodium iodide-based gamma spectrometers. Several new and promising formulations have been discovered and synthesized in small quantities, but there is a need for industrial crystal-growth facilities to find ways to produce practical sizes of high-quality scintillators at a reasonable cost. As an alternative to crystal growth, techniques that produce high quality, large volume scintillators with good spectroscopic performance from the consolidation of powders are highly desirable. Although most previous work has been done with oxide compounds, polycrystalline halide scintillators – formed from the new alkaline earth halides, the elpasolites, and other materials that demonstrate high performance in single-crystal form – would be of particular interest. It is important to incorporate elements with high atomic number in order to enhance the photoelectric effect. Also, a scintillator thick enough to absorb high energy gamma rays must also be very transparent to its own emitted light. A laboratory demonstration is expected in Phase I, while Phase II should lead to the development of a commercial process with a significant advantage over current crystal growth techniques.

Contact: David Beach, 202-586-0346, david.beach@nnsa.doe.gov

51b. Semiconductors for Gamma Spectroscopy
We are interested in promoting the industrial capacity to develop large volume, high quality radiation detector materials based on semiconductors. As an example, in the last three years, pixelated cadmium zinc telluride (CZT) detectors using depth correction have demonstrated resolution at room temperature (0.5% at 662 keV) that rivals high purity germanium (HPGe). Approaches of interest must address growth issues involving such semiconductor materials, so that reliable, high yield, rapid, and large volume growth is readily achievable at a reasonable cost. It should be recognized that good electronic transport properties are essential, such as electron and hole mobilities and lifetimes, which as a rule require extremely low concentrations of deleterious impurities and careful control of deliberate dopants. Phase I should result in the identification of a clear path to improving upon existing growth techniques. Phase II should include a demonstration of a material fabrication process that is free from dislocations, cracking, chemical heterogeneities, and minor crystalline phases, including precipitates.

Contact: David Beach, 202-586-0346, david.beach@nnsa.doe.gov

51c. Next Generation Radioisotope Handheld Identifier
Current scintillator-based radioisotope identifiers that use sodium iodide often do not perform well in a number of nonproliferation and safeguard applications. Although newer identifiers based on lanthanum bromide generally perform better, they are much more expensive and their performance at lower energies is actually inferior to sodium iodide. Recently, several new compounds have been identified that not only have a resolution comparable to lanthanum bromide, but also have improved proportionality and the potential for much lower cost. Thus, grant applications are sought to utilize these new materials to produce a next generation isotope identifier. In addition, it is highly desirable that proposed identifiers (1) utilize a solid-state alternative to a photomultiplier tube, and (2) contain sufficient computational power to allow a sophisticated, high confidence, isotope identification algorithm. Phase I should develop a clear system design with a quantitative assessment of the performance that would be achieved with this instrument. Phase 2 should involve the construction of a prototype instrument.

Contact: David Beach, 202-586-0346, david.beach@nnsa.doe.gov

51d. Next Generation Neutron Detector
New solid materials capable of detecting neutrons and distinguishing them from gamma rays are being developed, notably organic crystals grown from solution. Industrial-scale development of such technology would be a fruitful area for proposals to demonstrate instruments that exploit such materials. Important criteria for such devices are intrinsic efficiency for fission spectrum neutrons and pulse timing precision, as well as good gamma rejection ratio. Phase 1 would establish a pathway to production of significant quantities of detector material, while making use

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of materials supplied by NNSA laboratories. Phase 2 would expand the technology beyond the scale of individual exploratory experiments to the stage of employing kilogram quantities of high quality neutron detecting material in large detectors or arrays of modules.

Contact: David Beach, 202-586-0346, david.beach@nnsa.doe.gov

51e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: David Beach, 202-586-0346, david.beach@nnsa.doe.gov

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2. Bessiere, P. Dorenbos, C. W. E. van Eijk, K. W. Kramer, H. U. Gudel and A. Galtayries. Scintillation and anomalous emission in elpasolite Cs2LiLuCl6 : Ce3+. *Journal of Luminescence*, **117**:187-198, 2006.

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1. A.E. Bolotnikov, S.O. Babalola, G.S. Camarda, H. Chen, ; S. Awadalla,; Cui Yonggang, S.U. Egarievwe, P.M. Fochuk, R. Hawrami, A. Hossain, J.R. James, I.J. Nakonechnyj, J. Mackenzie, Ge Yang, Chao Xu, R.B. James, "Extended Defects in CdZnTe Radiation Detectors", *IEEE Trans. on Nucl. Sci*., 56(4), 1775 (2009)

2. Robert C. Runkle, L. Eric Smith, and Anthony J. Peurrung, "The photon haystack and emerging radiation detection technology", *J. Appl. Phys.* **106**, 041101 (2009).

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1. N.J. Cherepy, G. Hull, A. Drobshoff, S.A. Payne, E. van Loef, C. Wilson, K. Shah, U.N. Roy, A. Burger, L.A. Boatner, W-S Choong, W.W. Moses "Strontium and Barium Iodide High Light Yield Scintillators," Appl. Phys. Lett. 92, 083508 (2008).

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2. G. Hull, S. Du, T. Niedermayr, S. Payne, N. Cherepy, A. Drobshoff, and L. Fabris "Light Collection Optimization in Scintillator Based Gamma-Ray Spectrometers" Nucl. Instr. Meth. A, 588, 384 (2008).

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1. R. T. Kouzes, and J. H. Ely, "Status Summary of ^{3}He and Neutron Detection Alternatives for Homeland Security", PNNL-19360

2. K. Osberg,N. Schemm, S. Balkir, J. I Brand, M. S. Hallbeck, P. A. Dowben, M. W. Hoffman, "A Handheld Neutron-Detection Sensor System Utilizing a New Class of Boron Carbide Diode", IEE Sensors Journal, 6(6), 1531, (2006).

52. GLOBAL NUCLEAR SAFEGUARDS RESEARCH AND DEVELOPMENT

The Global Nuclear Safeguards Program supports NNSA's nuclear nonproliferation mission by developing innovative safeguards technologies to enhance verification of nuclear materials and activities. The program develops technologies to detect diversion of nuclear material from declared facilities; to detect undeclared nuclear material and activities; and to verify compliance with arms control treaties and agreements related to the control, production, or processing of nuclear material. The program includes R&D in nuclear (and relevant nonnuclear) measurements; information integration, and management; advanced tools for systems analysis; authentication, and containment, and surveillance.

52a. Safeguards Measurement Sensors

Grant applications are sought to develop technologies to enable the dramatic improvement of safeguards measurements, both nuclear and nonnuclear. Technologies of interest include (1) an enabling technology for sensor survivability in high radiation environments, (2) an enabling technology to reduce power requirements for remote monitoring, (3) enabling manufacturing techniques for innovative radiation sensors, (4) enabling information-processing techniques for multiplexed sensors or for the integration of large datasets. Grant applications must show a clear link between the proposed technology and the improvement in safeguards measurements.

Contact: Frances Keel, 202-586-2197, frances.keel@nnsa.doe.gov

52b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Frances Keel, 202-586-2197, frances.keel@nnsa.doe.gov

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1. "Safeguards to Prevent Nuclear Proliferation", March 2009. (Full text available at: http://www.world-nuclear.org/info/inf12.html).

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2. "The US Support Program to IAEA Safeguards", Modified June 5, 2008. (URL: http://www.bnl.gov/ISPO/ussp.asp).

3. Safeguards R&D Program in the United States presented at the 50th Anniversary meeting of Institute for Nuclear Materials Management, July 2008.

53. ADVANCED SIMULATION, ALGORITHMS AND MODELING

NA-22's Simulation, Algorithm and Modeling (SAM) Program supports the other programs within NA-22 by developing and exploiting models, simulations, advanced data processing concepts and algorithms to enable the detection and assessment of nuclear proliferation activities. SAM invests in high-impact, long-term, and high-risk theory, information science and technology research for facility modeling, geospatial analysis to transition between images and semantic meaning, advanced spectroscopic analysis and integrated modeling.

53a. Utilizing Human Computing to Annotate Geospatial Imagery

Training algorithms for image recognition require annotation of imagery, an expensive and laborious process requiring thousands of hours of time investment by the GS analysts. This project should develop a logistic framework enabling rapid parallel human annotation of geospatial imagery, design a set of tasks with challenges leading to a high quality annotation revealing the desired feature set in the imagery, create a set of imagery to test the resulting system, and conduct preliminary testing. When correctly presented using a gaming representation, the process of annotation could become easier and more engaging.

Contact: Alex Slepoy, 202-586-4812, Alexander.slepoy@nnsa.doe.gov

53b. Advanced Graphical Data Extraction

Often the most important information in a technical document is contained in graphs of data. OCR has existed for more than 30 years and commercially available products read a wide variety of fonts and languages. However, OCR does not accurately read important components of technical documents such as graphs and equations. Thus, applications are sought for graphical data extraction with advanced technical optical character recognition (OCR) that would add the ability to read and extract quantitative information from graphs embedded in technical documents. Graphs are usually composed of basic components, such as plotted data points, axes with numbers and text that identify the variables being plotted and curves that are fitted to the data. The desired output of this advanced algorithm would be digital arrays containing matched pairs (x, y) of data points with column headings derived from the axes of the graphs.

Contact: Alex Slepoy, 202-586-4812, Alexander.slepoy@nnsa.doe.gov

53c. Technological Dependency Database

Applications are sought to understand how technologies depend on other technologies. NNSA seeks theory for connecting a taxonomic hierarchical list of technologies with directed edges based on direct dependency. For example, electronic micro-fabrication depends on technology for growing inexpensive high purity Si polycrystalline materials. Due to the potentially very large task of compiling the above dependency data structure, NNSA is interested in both methods for automation in the dependency edge discovery as well as specific technology taxonomies.

Contact: Alex Slepoy, 202-586-4812, Alexander.slepoy@nnsa.doe.gov

53d. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Alex Slepoy, 202-586-4812, Alexander.slepoy@nnsa.doe.gov

REFERENCES

1. Seneviratne, L., "Image annotation through gaming (TAG4FUN)."

2. Rong Yan, "An Efficient Manual Image Annotation Approach based on Tagging and Browsing."

54. NUCLEAR DETONATION DETECTION

The Office of Nuclear Detonation Detection is responsible for the research and development necessary to provide the U.S. Government with capabilities for monitoring nuclear explosions. The optical waveform of atmospheric nuclear detonations is well understood and provides a way to quickly and positively identify that a detonation is nuclear. Optical waveforms from nuclear detonations are also a basis for an estimate of yield. Modern off-the-shelf electronics and networking infrastructure should make possible the production of low-cost systems for these purposes that could be widely fielded, including on buildings, towers, or vehicles.

54a. Time History of Optical Emissions
Grant applications are sought for ground-based systems that would detect and record the time history of optical emissions from a nuclear detonation (NuDet) in the atmosphere within 1 km of the surface. The system should consist of low-cost sensor and processing components. Consider yields of 20KT (See Glasstone, Figure 2.123 p. 69) and below, which must be measured both day and night within an environment that includes signals from natural and anthropogenic sources. The sensor system should permit economical balancing between networks with widely distributed but inexpensive sensing, reporting, and processing capability versus more elaborate and expensive point-specific capabilities. The statement of work should include proposing possible architecture, providing candidate sensor, recording, and processing nodes, acquiring background measurements, and demonstrating potential signal discrimination.

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Contact: Vaughn Standley, 202-586-1874, Vaughn.standley@nnsa.doe.gov

54b. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Vaughn Standley, 202-586-1874, Vaughn.standley@nnsa.doe.gov

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1. S. Glasstone and P.J. Dolan "The Effects of Nuclear Weapons", Third Edition, United States, Department of Defense and the United States Department of Energy, (1977).

55. RADIONUCLIDE MONITORING FOR NUCLEAR EXPLOSIONS

The Ground-based Nuclear Explosion Monitoring Research and Development (GNEM R&D) Program in the Office of Nuclear Detonation is sponsored by the U.S. Department of Energy's National Nuclear Security Administration's Office of Nonproliferation Research and Development. This program is responsible for the research and development necessary to provide the U.S. Government with capabilities for monitoring nuclear explosions. The mission of the GNEM R&D Program is to develop, demonstrate, and deliver advanced ground-based seismic, radionuclide, hydroacoustic, and infrasound technologies and systems to operational agencies to fulfill U.S. monitoring requirements and policies for detecting, locating, and identifying nuclear explosions (see Reference 1). Within the context of one or more of these technologies, research is sought to develop algorithms, hardware, and software for improved event detection, location, and identification at thresholds and confidence levels that meet U.S. requirements in a cost-effective manner. Superior technologies will help improve the Air Force Technical Applications Center's (Reference 2) ability to monitor for nuclear explosions, which are banned by several treaties and moratoria. Annual research progress of the GNEM R&D program is available in proceedings posted on-line (see Reference 3).

Grant applications responding to this topic must (1) demonstrate how proposed approaches would complement, and be coordinated with, ongoing or completed work; and (2) address the manufacturability of any instruments or components developed.

55a. Improved Xenon Collection
Xenon collection systems consist of a several gas processing elements, including; pre-concentration, separations, and purification stages. All of these processes require special gas handling components that are not readily available as commercial off-the-shelf items. This focus area is aimed at addressing the challenges of processing gas in each of these sub-systems where a key specification is the reduction of contamination by using gas-tight pumps.

Grant applications are sought for innovative solutions to improve high-volume air sampling, gas separation and transfer in xenon collection systems. Gas transfer and separation components of interest include small, gas-tight, oil-free compressors; vacuum pumps; and gas transfer syringes:

- Compressors should be capable of up to 40 liters per minute continuous flow at 5 to 7 barg (Bar, gauge pressure), gas-tight, and oil free, and should operate on 120 VAC (50 and 60 Hertz). Compressors should be designed for continuous duty, for durations in excess of 6 months prior to any compressor maintenance. Physical dimension less than 12" x 12" x 12" and less than 30 lbs.
- Similarly, small volume, gas transfer pumps should be small and gas-tight, and should achieve ultimate vacuum (<0.1 Torr) on the inlet while also compressing the output to 4 – 5 barg. The transfer pump should be powered by either 24 VDC or 120 VAC (50 and 60 Hertz). The desired application is to transfer gas (at atmospheric pressure) from a 1 liter sample container (down to a final pressure of 0.1 Torr) into a secondary smaller container (or equivalent) to a pressure of 4 – 5 barg in less than 2 minutes.
- For relatively small volume transfers (<1 standard liter of gas per cycle), transfer pumps may be in the form of a syringe-style pump or a continuous-duty mechanical design. The envisioned application would have a ~ 1 liter syringe draw sample from a container or transfer pump and then redirect it, at higher pressure, to another process stream. The external leak rate under either vacuum or pressure should be less than 0.01 standard cm^3 of air / sec.

Optimal factors for these components include gas-tightness, durability, operation at 120 VAC or DC power, and the ability to be contamination free (i.e., minimal use of low vapor pressure lubricants). A demonstration of the mean time between failure (MTBF) specifications is highly desirable (although due to the short time duration of the phase I portion of the project at defendable approximation to the MTBF is suitable).

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

55b. Stable Xenon Quantification Module Development

Grant applications are sought for the quantification of the amount of stable xenon in a gas sample undergoing nuclear activity analysis, as part of a radioxenon monitoring instrument. Conceptually, a mixture of xenon in nitrogen (or helium) will be volumetrically expanded out of a small volume nuclear detector (4 cc's) into an evacuated quantification manifold. The anticipated quantity of xenon available for the measurement is 0.25 cm^3 (standard temperature and pressure). The amount of nitrogen (or helium) is anticipated to be in the range of 0.25 – 0.75 cm^3 (STP). The objective is to derive the amount of stable xenon in this gas sample from independent measures of pressure, temperature, and mole fraction of xenon in order to calculate the stable volume (standard cubic centimeters). Therefore the quantification system should include a high quality pressure transducer, temperature probes and binary gas analyzer. Important specifications include:

- The physical volume of the system should be accurately known with low uncertainty (<1%).
- The combined relative uncertainty (random and systematic) in the reported xenon volume should be less than 3% (1σ).
- The technology should be robust, field deployable and not require regular calibration (6 months between calibration checks).

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This measurement is challenging due to the low pressures expected during the quantification, placing constraints on the binary gas analysis technique, therefore it is expected that new gas sensing technologies will be developed under this project.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

55c. Remote Field Radioxenon Monitoring System

Grant applications are sought for the development of a deployable system capable of continuous environmental monitoring for ^{133}Xe and ^{135}Xe via gamma detection. Each node should consist of a robust, fieldable gamma detector (e.g., CsI or NaI), acquisition electronics and data analysis algorithms. Data analysis should consist of both gross count and spectral identification. The system should have the option of transmitting data packets to a central location via wireless technology in addition to manual data transfer. An integrated data management tool should also be included allowing for rudimentary data manipulation and display. Specifications include:

- Gamma detection of 80 keV photon from ^{133}Xe and 250 keV photon from ^{135}Xe
- Detection of ~100 mBq/m^3 levels are desired but detection of 5 Bq/m^3 or lower are acceptable
- Portable detector for short term installation
- GPS enabled for time and location input
- Low Power

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

55d. Medical Isotope Stack Monitoring

Understanding the gaseous radionuclide emissions from Medical Isotope production facilities is an important element in quantifying sources of background relevant to nuclear explosion monitoring.

Grant applications are sought for an integrated medical isotope stack monitoring system. The system should be capable of determining the activity of a range of radionuclides via spectroscopy using automated peak fitting routines. In addition, stack flow rates shall be used to compute the activity concentration of the radionuclides (i.e., Bq/m^3 effluent). A secondary dilution system may be used to reduce the high activities expected during production intervals, this additional dilution must also be factored into the calculation of activity concentration. Software database management tools should be included allowing for efficient data archiving and analysis. Specific requirements are listed below:

- Important Radionuclides: ^{131m}Xe, ^{133}Xe, ^{133m}Xe, ^{135}Xe, ^{85m}Kr, ^{131}I, ^{133}I and ^{135}I
- Stack flow rate input
- Flow rate and dilution monitoring through detector
- Automated peak fitting, radionuclide identification and variable integration time
- An additional filtering system (e.g., charcoal or particulate) for iodine with its own separate detector system will likely be necessary.
- System must have high dynamic range, from background (10^3 Bq/m^3) to high release levels ~10^{12} Bq/m^3 (added range up to 10^{14} Bq/m^3 would be desirable)

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- Measurement precision of +/- 10%

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

55e. Cryogenic Thermal Break

Mechanical cryogenic coolers can greatly improve the efficiency of a xenon collection system. Coolers can be used in all of the important sub-systems, including pre-concentration, separations and purification. The amount of cooling (i.e., thermal lift) and temperature varies for each of these separate processing steps. For many gas processing schemes it is common to operate the component attached to the cooler at low temperature for adsorption and then heat the same component to high temperature to desorb the previously adsorbed species. One technical challenge that can limit design options is the *maximum allowable* temperature of the coolers cold-head when not in operation; many of these cold-heads are rated to 50 C or less. For maximum flexibility it is desirable to heat gas adsorption components to temperatures in excess of 250 C.

Grant applications are sought for a cryogenic thermal break, defined as a device mounted to a mechanical cooler's cold-head that allows maximum thermal lift during the cold cycle and minimizes thermal conductance to the cold-head during heating. The device should:

- Adaptable to fit a variety of cold-heads whose diameter ranges from 1" to 3".
- The working end of the device should allow for a variety of mounting options for attaching different components (e.g., a series of mounting holes on a flat platform).
- Should operate from -200 C for cooling applications and up to +300 C for heating applications.
- Device itself should be as compact as practical and have minimal ancillary control equipment.
- Able to operate at atmospheric pressure in an insulated enclosure.
- Will be attached to coolers with thermal lift in the range of 2-3 Watts at -200C up to a 100 Watts at -50C.
- The time scale between thermal short and thermal open should be less than 5 minutes.
- The device should be able to operate without maintenance for at least 1 year with thermal cycling 4 times per day.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

55f. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

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1. "Nuclear Explosion Monitoring Research and Engineering Program Strategic Plan, National Nuclear Security Administration," September 2004. (Document No. DOE/NNSA/NA-22-

NEMRE-2004) (Full text available at https://na22.nnsa.doe.gov/cgi-bin/prod/nemre/index.cgi?Page=Strategic+Plan)

2. U.S. National Data Center, Air Force Technical Applications Center, http://www.tt.aftac.gov/wrt/

3. Annual Research Review Proceedings for Ground-Based Nuclear Explosion Monitoring Research and Engineering, sponsored by the National Nuclear Security Administration and the Air Force Research Laboratory. (Available at: https://na22.nnsa.doe.gov/proceedings)

56. COMPACT SEISMO-ACOUSTIC MONITORING SYSTEM

Growing efforts to study explosion monitoring in the local range (0 to 200 km) have identified a need for an improved and simplified sensor package. What would be useful is a compact system to record 3 components of seismic motion as well as acoustic pressure.

56a. Meet Current Industry Standards for Seismic Recording
Grant applications are sought for seismo-acoustic recorders that meet current industry standards for seismic recording. The recorder characteristics should meet current industry standards for seismic recording: 24 bit resolution, high dynamic range (> 120 dB), precise timing (accuracy better than 0.001 s), high sample rate (up to 2 kHz) and environmentally stable (at least -20 to +50 C, watertight, etc.).

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

56b. High Fidelity Sensors with Telemetry Connectivity
Grant applications are sought for high fidelity seismo-acoustic sensors with telemetry connectivity. The sensors should be high fidelity, have a broad frequency response appropriate for recording explosions in the local range (approximately 0.1 to 1000 Hz), and handle a dynamic range from low noise background to the higher amplitudes expected in the near field (perhaps as high as 0.1g acceleration equivalent for seismic motion). It should be possible to connect the recorder to telemetry.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

56c. Small, Light Package with Low Power Consumption
Grant applications are sought for a small, light recording system with low power consumption. The entire package should be small and light (a single installer/individual should be able to carry a few complete systems) but be capable of recording continuously for up to a year. Low power consumption is very important.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

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56d. Continuous and/or Triggered Recording

Grant applications are sought for continuous and/or triggered seismic recording. The recorder should operate in continuous recording and/or triggered modes, and the user should be able to select the mode to be sent to a telemetry system. Innovative sensors that would support such a package are also of interest.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

56e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Leslie Casey, 202-586-2151, leslie.casey@nnsa.doe.gov

REFERENCES

1. L.A. Casey and W.R. Bell, "Nuclear Explosion Monitoring Research and Development Roadmaps," Proceedings of the 2010 Monitoring Research Review, September 2010 (Available at: https://na22.nnsa.doe.gov/mrr/2010/PAPERS/01-01.PDF).

57. ADVANCED SEPARATIONS CHEMISTRY TOOLS

Separations chemistry is practiced broadly for a variety of applications related to DOE missions. These applications range from environmental sampling and analysis of trace constituents for nuclear forensic analysis of radioactive samples. New chemical separations methods are needed to enable researchers to rapidly and reproducibly isolate several chemical species of interest that are in liquid mixtures at relatively low concentrations. Advances in technical tools that perform efficient separations can directly impact the pace and extent of scientific study of species that are in low concentrations but whose presence, if detected and quantified, has significant diagnostic value.

57a. Development of Resin Material Binders Compatible with Emerging Highly Selective Ligands

Extractions that now use the ligand 4-chloro-2-[(6-chloro-7-methyl-2H-1,3-benzoxazin-3(4H)-yl)methyl]-5-methylphenol, and related ligands, are of interest to perform in ways that are more efficient – that is, that are more rapid, and that achieve a high degree of separation between the analytes that this ligand sequesters and other species in the original liquid mixture. These efficiencies can be obtained by the development and use of an appropriate resin (binder) material that is compatible with this ligand and that enables it to be used in a column, for use in extraction chromatography.

Currently this ligand is used in a solvent extraction (SX) method. SX is not a rapid method of separation, nor is it an environmentally friendly process as large amounts of toxic solvents are used. The binding of this ligand to a solid support would greatly increase the ease and speed of the separation.

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Grant applications are sought for the development of a resin material that incorporates this ligand in the surface area of an extraction column. Properties of interest include minimal degradation of the ligand performance in its degree of separations (e.g., as measured by decontamination factors in comparison to SX or batch mode tests), flow-through rates, and the rapidity of separations achieved with the new resin. The references below describe the synthesis of this ligand type and initial data on the SX of the ligand for Ga(III).

Contact: Tom Kiess, 202-586-7664, Thomas.kiess@nnsa.doe.gov

57b. Automated Evaporation of Aqueous Acidic Solutions

Aqueous-based separations are used widely, in applications that include medical isotope production and the isolation of trace species of interest in nuclear forensics analyses. These methods rely on the transposition of solutions between separation steps. An automated system that can rapidly transpose many solutions without cross-contamination would improve the timeliness and fine-tuned control that can be applied to many separations processes.

A major time- and labor-intensive step in aqueous-based separations of various elements often is not the separation itself, but rather the conversion of the carrier solvent from one type to another. This conversion typically involves evaporating an aqueous solution to dryness and reconstituting the remaining solute residue in another solvent matrix. This evaporation is done under controlled conditions because of the need to carefully ensure the solvent is fully evaporated while the solute product of interest is not destroyed by overheating. This controlled evaporation is a process that could be automated.

Grant applications are sought for the development of an instrument designed to drive off water and acid from a sample (through heating or another method) under automated control. Such a system would need to be compatible with various acid vapors (specifically to include HNO_3, HCl, HF, and $HClO_4$). Important features are the sample throughput and routing of off-gases – so as to be able to process large numbers of samples (e.g., as many as 24, each of volume 0.1-10 milliliters) without cross contamination between them.

Contact: Tom Kiess, 202-586-7664, Thomas.kiess@nnsa.doe.gov

57c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Tom Kiess, 202-586-7664, Thomas.kiess@nnsa.doe.gov

REFERENCES

Subtopic a:

1. Hirayama, N. Horita, Y. Oshima, S. Kubono, K. Kokusen, H Honjo, T. Selective Extraction of Gallium (III) Using Tris(2-hydroxy-3.5-dimethylbenzyl)amine, *Analytical Sciences* **2001** *17*, 257-260 and references therein.

2. Hultzsch, K. *Chem Ber*, **1949** *82,* 16 ff.

3. Komissarova, N. Belostotskaya, I. Shubina, O. Ershov, V. Vosnesenski, V Chervin, I. Anamalous Duff Reaction with 2,4-di-tert-butylphenol. *Institute of Physical Chemistry, Academy of Sciences of the USSR, Moscow (Engl. Trasl.)* **1988**; *Izvestiya Akademii Nauk SSSR, Seriya Khimicheskaya,* **1988** *9* 2186 ff.

Subtopic b:

1. United States Patent 4604363

2. United States Patent 5514336

58. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power provides over 20 percent of the U.S. electricity supply without harmful greenhouse gases or air pollutants, including those that may cause adverse global climate changes. New methods and technologies are needed to address key issues that affect the future deployment of nuclear energy and to preserve the U.S. leadership in nuclear technology and engineering, while reducing the risk of nuclear proliferation. This topic addresses several of these key technology areas: improvements in nuclear reactor technology for existing light water reactors and evolutionary LWR and gas-cooled reactor designs, advanced instrumentation and control (I&C) for very high temperature gas-cooled reactor applications, advanced I&C for use in high neutron irradiation environments for the Next Generation Nuclear Plant (NGNP) gas-cooled reactor designs, and advanced technologies for the fabrication, characterization and non-destructive testing of high quality nuclear reactor fuel for LWR and Generation IV reactor designs which include advanced fuel cycle management related technologies. Of particular interest are grant applications that propose the use of the Idaho National Laboratory's Advanced Test Reactor National Scientific User Facility for Phase I and/or Phase II. However, grant applications that deal with nuclear materials, irradiation effects, chemistry, and/or corrosion research are also not of interest for this topic and should be submitted instead under Topic 20.

Grant applications are sought in the following subtopics.

58a. New Technology for Improved Nuclear Energy Systems

Improvements and advances are needed for reactor systems and component technologies that ultimately would be used in the design, construction, or operation of existing and future nuclear power plants, and Generation IV nuclear power systems [see references 1-5]. Grant applications are sought: (1) to improve and optimize the performance of the nuclear power plant and its systems, along with component instrumentation and control, by developing and improving the reliability of advanced instrumentation, thermocouples, sensors, and controls, and by increasing the accuracy of measuring of key reactor and plant parameters [6, 7]; (2) to improve monitoring of plant equipment performance and aging, using improved diagnostic techniques for in-service and non-destructive examinations [8]; (3) for advanced instrumentation, sensors, and controls for

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very high temperature gas cooled reactor (Generation IV) designs that can withstand temperatures in excess of 1600° C; and (4) for advanced instrumentation, sensors, and controls for the very high irradiation environments (> 10^{15} n/cm^{2} sec neutron flux levels) that will be encountered in advanced Generation IV high temperature gas reactor designs and sodium fast reactors [7, 9, 10]. Grant applications that propose to use the Idaho National Laboratory (INL) Advanced Test Reactor (ATR) National Scientific User Facility [11] for demonstrating the performance of the instrumentation, sensors, or thermocouples are particularly sought and will need to prove technical feasibility prior to their insertion into the ATR for irradiation testing.

Grant applications that address the following areas are NOT of interest and will be declined: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; computer software enhancements; and U. S. Nuclear Regulatory Commission probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues.

Contact: Suibel Schuppner, 301-903-1652, suibel.schuppner@nuclear.energy.gov

58b. Advanced Technologies for the Fabrication, Characterization of Nuclear Reactor Fuel for Generation IV Reactor Designs, and Fuel for Advanced Fuel Cycle Research and Development

Improvements and advances are needed for the fabrication, characterization and non-destructive examination of nuclear reactor fuel with technologies that could: (1) develop advanced automated, continuous vs. batch mode process fabrication, characterization, and non-destructive testing TRISO fuel for Advanced Gas-Cooled Reactors/NGNP applications [12, 13]; and (2) provide new innovative LWR and fast reactor advanced fuel fabrication techniques capable of dealing with actinide-bearing ceramic and metal alloys, and (3) develop radiation-tolerant electronics for characterization instrumentation for use in hot cell fuel/clad property meashrements [9, 10]. Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets or TRSIO particles for demonstration. Actual nuclear fuel fabrication and handling applications may be proposed to use the INL ATR National Scientific User Facility [11], and its hot cells and fuel fabrication laboratories, or the Oak Ridge National Laboratory Advanced Gas Reactor TRISO fuels laboratory facilities [12, 13] to demonstrate the techniques and equipment developed. Actual nuclear fuel specimens may be considered for ATR or ORNL High Flux Irradiation Reactor (HFIR) will need to prove technical feasibility prior to their insertion into the ATR or HFIR for irradiation testing.

Grant applications that address the following areas are NOT of interest and will be declined: Spent fuel separations technologies used in the Fuel Cycle Research and Development Program [9, 10] and applications that seek to develop new glove boxes or sealed enclosure designs.

Contact: Madeline Feltus, 301-903-2308, Madeline.feltus@nuclear.energy.gov

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58c. Materials Protection Accounting and Control for Domestic Fuel Cycles

Improvements and advances are needed for the development, design and testing of new sensor materials and measurement techniques for nuclear materials control and accountability (including process monitoring) that increase sensitivity, resolution, radiation hardness, while decreasing intrusiveness on operations and the cost to manufacture. In addition, concepts and integration of safeguards features into facility/process design are being sought. Grant applications are sought for: (1) Sensors based on radiation detection; (2) New technologies to replace He-3 for neutron detection in accountability instruments; (3) New active interrogation methods, including basic nuclear data (neutron and photo fission, nuclear resonance fluorescence); (4) Non-radiation based (stimulated Raman, laser-induced breakdown spectroscopy, fluorescence, etc.); and (5) Safeguards and security by design concepts. Grant applications are also sought for the development of new methods for data validation and security, data integration, and real time analysis with defense-in-depth and knowledge development of facility state during design.

Contact: Daniel Vega, 301-903-7722, daniel.vega@nuclear.energy.gov

58d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Madeline Feltus, 301-903-2308, Madeline.feltus@nuclear.energy.gov

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59. SEARCH, DISCOVERY, AND COMMUNICATION OF SCIENTIFIC AND TECHNICAL KNOWLEDGE IN DISTRIBUTED SYSTEMS

Scientific discovery underpins the advances the Nation needs to power our economy and develop energy independence. As science progresses only if knowledge is shared, the acceleration of the sharing of scientific knowledge speeds up scientific progress. In today's world, this knowledge is embodied in text (journal articles, e-prints, conference proceedings, report literature) as well as in many digitized non-text formats (numeric data, images, video, streaming media, and more) hosted on geographically dispersed servers. Researchers would benefit greatly if they had ways to simultaneously search across these vast resources of text and/or non-text and find the specific knowledge they need in an integrated manner. While technology has significantly accelerated the availability and quantity of scientific information on the Web, the tools and capabilities to search and find that information have not kept pace with its growth. This lag has created a

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chasm in the capability to globally search the Internet, especially with regard to distributed scientific and technical information of merit.

59a. Identifying, Searching, Accessing, and Communicating Science (Especially as Presented in Scientific and Technical Databases, Data Sets, and Multimedia)

Despite major advances in technological approaches to search and retrieve textual R&D information through federated deep-web resources, a number of significant gaps prevent the search and access of the full range of information and data types. Specifically, gaps exist in (1) the use of real-time multilingual translations to enable access to research in other languages; (2) scaling federated search applications in ways that properly balance search engine speed and comprehensiveness; (3) eliminating duplications across search results; (4) integrating Web 2.0 capabilities, including social networking (e.g. commenting, tagging, rating, or collaborative filtering) that promotes interactive collaborations across scientific communities; (5) integrating multimedia and numeric data access into traditional textual search and retrieval; and (6) integrating Mobile Web delivery. Grant applications are sought to address these gaps with innovative technologies that are capable of being adopted across a heterogeneous mix of next generation or existing applications. The intended audiences for proposed technologies include science and engineering researchers, science-attentive citizens, and/or students at various levels.

Contact: Dr. Walter L. Warnick, 301-903-7996, Walter.Warnick@science.doe.gov

59b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Dr. Walter L. Warnick, 301-903-7996, Walter.Warnick@science.doe.gov

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60. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH INTENSITY ACCELERATORS

The DOE High Energy Physics (HEP) 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. The strategic plan for HEP includes initiatives on the intensity frontier, relying on accelerators capable of delivering very high average beam intensity at multi-GeV energies, i.e. beam powers measured in megawatts. Beams are typically composed of protons or ions. The DOE HEP program seeks to develop advanced technologies that can be used to support MW-class facilities in a cost effective manner.

Grant applications are sought in the following subtopics.

60a. Accelerator Development and Modeling of Advanced Concepts

Grant applications are sought to develop new or improved accelerator designs and supporting modeling that can provide efficient acceleration of intense particle beams in either linacs or synchrotrons. Efficient acceleration refers to beam losses of less than 1 W/m. Topics of interest include: (1) linac configurations, either pulsed or CW, capable of delivering >1 MW beams at energies between 1-10 GeV; (2) halo formation in pulsed or CW linacs; (3) concepts for high intensity rapid cycling synchrotrons; (4) space-charge mitigation techniques; (5) new methods for multi-turn H^- injection, including laser stripping techniques; and (6) higher order mode generation, propagation, and suppression in acceleration cavities.

The HEP application of interest is for a high intensity proton source to support intensity frontier programs including long baseline neutrino beams and rare processes experiments. Other possible applications include high-intensity proton drivers for neutron production, waste transmutation, energy production in sub-critical nuclear reactors, medical proton therapy, and radioisotope production.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60b. Superconducting Radiofrequency Cavities

Grant applications are sought for the development of superconducting radiofrequency cavities for acceleration of proton and ion beams, with relativistic betas ranging from 0.1 to 1.0. Frequencies of current interest include 325, 650, and 1300 MHz. Continuous wave (CW) cavities are of the greater interest, although pulsed cavities could also be supported. Accelerating gradients in the range of 15-18 MV/m at Q_0 in excess of 1E10 are desirable. Topics of interest include: (1) cavity designs; (2) cavity fabrication alternatives to electron beam welding, including for example hydroforming and automatic TIG or laser welding of cavity endgroups; (3) other cavity and cryomodule cost reduction methods; (4) cw power couplers at >50kW; (5) fast tuners for microphonics control; (6) higher order mode suppressors, including extraction of

HOM power via the main power coupler ; (7) ecologically friendly or alternative cavity surface processing methods; (8) alternatives to high pressure rinsing that would allow in-situ cleaning of cavities to control field emission; and (9) high resolution tomographic x-rays of electron beam welds in cavities.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60c. Radio Frequency Power Sources and Components

Grant applications are sought for the development of power sources for cavities operating with 1-10 mA of average beam current in linacs capable of accelerating protons and ions to several GeV. Frequencies of interest include 325, 650, and 1300 MHz. Continuous wave (CW) applications are the primary interest. Examples of systems of interest include, but are not limited to: klystrons, solid state, inductive output, and phase locking magnetron devices; and the associated power supplies/modulators.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60d. High Gradient Tunable RF Cavities for Rapid Cycling Synchrotrons

Grant applications are sought to develop high gradient cavities that can be utilized in synchrotrons with repetition rates in the range of 5-50 Hz, with frequency swings corresponding to beta variations from 0.9-1.0. Cavity gradients in excess of 20 MV/m are desirable. Topics of interest include: (1) cavity (including tuner) designs; (2) cavity fabrication techniques; and (3) power sources.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60e. High Reliability Ion Sources

Grant applications are sought for the design, and possibly demonstration units, of CW proton and H^- sources capable of operating at up to 10 mA. The primary interest is in sources that can be fabricated with high reliability, meaning source lifetime of greater than one month.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60f. Beam Choppers, Bunchers, and Transverse Deflectors

Grant applications are sought for beam deflecting devices that can be used to remove or deflect proton or ion bunches for the purpose of forming variable bunch patterns of use in high intensity proton accelerators. Topics of particular interest include: (1) wideband beam choppers capable of removing beam from a dc source at energies in the 2-3 MeV range; specifically with capabilities of providing arbitrary chopping patters with a bandwidth of >300 MHz; and (2) narrowband transverse deflecting cavities capable of CW operation at a few hundred MHz, with deflecting fields of ~25 MV/m.

In addition grant applications are sought for buncher cavities that can be utilized in the initial acceleration stages of proton or ion accelerators.

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Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

60g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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61. HIGH-SPEED ELECTRONIC INSTRUMENTATION FOR DATA ACQUISITION AND PROCESSING

The DOE supports the development of advanced electronics and for the recording, processing, storage, distribution, and analysis of experimental data that is essential to experiments and particle accelerators used for High Energy Physics (HEP) research. Areas of present interest include event triggering, data acquisition, high speed logic arrays, and fiber optic links useful to HEP experiments and particle accelerators. Grant applications must clearly and specifically indicate their relevance to present or future HEP programmatic activities.

Although particle physics detector and data processing instrumentation typically are developed in large collaborative efforts at national particle accelerator centers, there are efforts where small businesses can make innovative and creative contributions. Applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available by institution at http://www.hep.net/sites/directories.htlml.

Grant applications are sought in the following subtopics:

61a. Special Purpose Chips and Devices for Large Particle Detectors

Grant applications are sought to develop 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, pico-second-resolution time-to-digital converters, controllers, and communications interface devices.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

61b. Circuits and Systems for Processing Data from Particle Detectors

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

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

61c. Systems for Data Analysis and Transmission

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

Grant applications also are sought for the innovative use of fiber optic links and/or commodity high-bandwidth networks for high-rate transmission of collected data between particle detectors and data recording or control systems. Approaches of interest should demonstrate technologies that feature one or more of the following characteristics: low noise, radiation tolerance, low power consumption, high packing density, and the ability to handle a large number of channels at very high rates.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

61d. Enhancements to Standard Interconnection Systems

Much of the electronics instrumentation in use in HEP is packaged in one of the international module inter-connection standards (e.g., VMEbus, PCIExpress, or high speed serial interfaces). Grant applications are sought to develop (1) new modules that will provide capabilities not previously available; (2) technology to substantially enhance the performance of existing types of modules; and (3) 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.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

61e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

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62. HIGH ENERGY PHYSICS COMPUTER TECHNOLOGY

The DOE supports the development of computational technologies essential to experiments and particle accelerators used for High Energy Physics (HEP) research. Areas of present interest include scalable clustered computer systems, distributed collaborative infrastructure, distributed data management, and analysis frameworks, and distributed software development useful to HEP experiments and particle accelerators. Grant applications must clearly and specifically indicate their relevance to present or future HEP programmatic activities.

Although particle physics computer systems and software development typically occur in large collaborative efforts at national particle accelerator centers, there are efforts where small businesses can make innovative and creative contributions. Applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available by institution at http://www.hep.net/sites/directories.htlml.

Grant applications are sought in the following subtopics.

62a. Large Scale Computer Systems

Grant applications are sought to develop (1) improvements to the wide area network fabric used by the experimental HEP community; (2) improvements to the reliability of cyber security systems protecting distributed storage and job management systems; and/or (3) improvements to the reliability and performance of data systems for HEP, which include permanent and temporary storage approaching exabyte scale. Proposed efforts must address identified computing problems related to diverse, large scale computing systems that support particle physics data processing and analysis.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

62b. Computational Methods for Petascale Physics

The international nature of HEP experiments and their large computing resource requirements drive the current HEP paradigm of handling and analyzing experimental data in a highly distributed fashion. By aggregating world-wide computing resources from HEP and other disciplines, initiatives like the Open Science Grid [19] aim to enable a federated computing model for HEP and other participating disciplines. Grant applications are sought to support the design, implementation, and operation of distributed computing systems comprising many distributed Petaflops of CPU power and distributed petabytes of data. Areas of current interest include middleware development for grid-enabled systems, distributed data management and analysis frameworks, distributed system configuration tools, monitoring and accounting tools, and security assurance tools for a distributed environment.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

62c. Software to Support Collaborations of Dispersed Researchers

Grant applications are sought to develop advanced software to strengthen the ability of dispersed particle physics researchers to collaborate and to address problems related to the acquisition, handling, storage, analysis, and visualization of large datasets. Areas of interest include (1) software project management tools; (2) visualization and software environments appropriate for physics analysis; (3) software to support data systems distributed over a wide area network; (4) software development tools for the production of computer software to meet identified problems related to distributed, large-scale software development, configuration management, and data analysis – approaches of interest include distributed portable testing and Computer Aided Software Engineering, such as configuration management tools for a portable, distributed environment; (5) algorithms and software tools for pattern recognition and optimization of data analysis; and (6) tools for improvements to the performance, verification, or validation of large software codes, such as found in the LHC experiments.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

62d. Web Tools and Associated Infrastructure to Support Collaborations

Grant applications are sought to develop advanced web tools and associated infrastructure technologies to strengthen the ability of dispersed particle physics researchers to collaborate. Areas of interest include (1) client-server frameworks and Web tools for creating collaborative environments, facilitating remote participation of detector experts at the data collection stage, and/or allowing collaborators real-time two-way participation in remote meetings; (2) computer system components and supporting software incorporating the use of Quality of Service features generally available in wide area networks; (3) portable systems to hold very large collections of data of the type created in connection with the operation of very large detectors, along with data management tools; (4) framework, interconnects, and other peripherals which allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual; (5) web tools for remote data selection ("skimming");

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

62e. Simulation and Modeling Techniques and Systems

Grant applications are sought to develop advanced computing tools and software for high energy physics simulation and modeling. Topics of interest include simulation and modeling algorithms for high energy physics processes, particle detectors, and theoretical calculations. Grant applications also are sought in areas of simulation support – such as frameworks for the management, configuration, custody, and dissemination of simulation and modeling data – in order to enable sharing by multiple experiments and theory research groups.

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Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

62f. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Alan Stone, 301-903-7998, Alan.Stone@science.doe.gov

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16. "CHEP'07 [Computing in High Energy Physics Conference]," Victoria, BC, Canada, Sept. 2-4, 2007, Website. (Website, including Conference papers at: http://www.chep2007.com/)

17. Open Science Grid Website. (URL: http://opensciencegrid.org)

63. HIGH ENERGY PHYSICS DETECTORS

The DOE supports research and development in a wide range of technologies essential to experiments in High Energy Physics (HEP) and to the accelerators at DOE high energy accelerator laboratories. The development of advanced technologies for particle detection and identification for use in HEP experiments or particle accelerators is desired. Broadly the areas of interest are improvements in the sensitivity, robustness, and cost effectiveness of particle detectors. Principal areas of interest include particle detectors based on new techniques and technological developments, or detectors that 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 or with significant improvement, in order to either extend basic HEP experimental research capabilities or result in less costly and less complex apparatus. Devices which exhibit insensitivity to very high radiation levels have recently become extremely important. Grant applications must clearly and specifically indicate their particular relevance to HEP programmatic activities.

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

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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. For example with respect to radiation hardness, energy, position, and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, compactness, cost, etc. Electromagnetic calorimeters, also called shower counters or gamma ray detectors, must be optimized for photons with energies above 1 GeV. X-ray detectors are not relevant to this topic.

Grant applications are sought in the following subtopics:

63a. Particle Detection and Identification Devices

Grant applications are sought for novel ideas in the areas of charged and neutral particle detection and identification that could lead to improvements in the sensitivity, robustness, or cost effectiveness of particle detectors. These include ideas to advance the utility of detectors for the Energy Frontier such as at an upgraded or future collider; at the Intensity Frontier such as at a future long baseline neutrino experiment; and at the Cosmic Frontier such as a new Dark Matter detector. Examples include, but are not limited to, semiconductor particle detectors (silicon, CVD diamond, or other semiconductors), light-emitting particle detectors (scintillating materials including fibers, liquids, and crystals or Cherenkov radiators), photosensitive detectors that could be used with light-emitting detectors (photomultipliers, micro-channel plates, photosensitive semiconductors), and gas or liquid-filled chambers (used for particle tracking, in electromagnetic or hadronic calorimeters, and in Cherenkov or transition radiation detectors). Grant applications also are sought for systematic studies of radiation aging of materials used in particle detectors.

Contact: Fred Borcherding, 301-903-6989, frederick.borcherding@science.doe.gov

63b. Detector Support and Integration Components

HEP experiments frequently require high performance detector support that will not compromise the precision of the detectors. Therefore, grant applications are sought for components used to support or integrate detectors into HEP experiments. The support components must be well matched to the detectors and possess some or all of the following features: low mass, high strength or stiffness, low intrinsic radioactivity, exceptionally high or exceptionally low thermal conductivity, and low cost. Grant applications also are sought for alignment systems, cooling systems, and radiation-hard low voltage power supplies for digital and analog electronics.

Contact: Fred Borcherding, 301-903-6989, frederick.borcherding@science.doe.gov

63c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Fred Borcherding, 301-903-6989, frederick.borcherding@science.doe.gov

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

The Department of Energy High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this research in high-field superconductor and superconducting magnet technologies. This topic addresses only those superconductor and superconducting magnet development technologies that support dipoles, quadrupoles, and higher order multipole corrector magnets for use in accelerators, storage rings, and charged particle beam transport systems.

Grant applications are sought in the following subtopics:

64a. High-Field Superconducting Wire Technologies for Magnets

Grant applications are sought to develop new or improved superconducting wire technologies for magnets that operate at a minimum of 12 Tesla (T) field, with increases up to 15 to 50 T sought in the near future (three to five years). Vacuum requirements in accelerators and storage rings favor operating temperatures of 1.8 to 20 K. Stability requirements for magnets dictate that the effective filament diameter should be less than 30 micrometers. Upgrades of existing particle accelerators will require some magnets that operate under a high radiation (and thermal) load. New or improved technologies must demonstrate: (1) property improvements such as higher critical current densities and higher upper critical fields, (2) the manageable degradation of these properties as a function of applied strain, and (3) low losses in changing transverse magnetic fields, such as for twisted round multi-filamentary wires. Any proposed process improvements must result in equivalent performance at reduced cost. All grant applications must focus on conductors that will be acceptable for accelerator magnets, especially with regard to the operating conditions mentioned above, and must address plans to physically deliver a sufficient amount of material (1 km minimum length) for winding and testing in small dipole or quadrupole magnets.

Contact: Bruce Strauss, 301-903-3705, bruce.strauss@science.doe.gov

64b. Superconducting Magnet Technology

Grant applications are sought to develop: (1) improved instrumentation to measure properties (such as local strain, temperature, and magnetic field) which are directly applicable to the testing of superconducting magnets; (2) improved current lead and current distribution systems, based on high-temperature superconductors, for application to superconducting accelerator magnets – requirements include an operating current level of 5 kA or greater, stability, low heat leak, and good quench performance; (3) alternative designs – to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets – that may be more compatible with the more fragile A-15, and the HTS, high-field superconductors (including open midplane magnest as needed in Muon Collider design); (4) designs for bent (e.g., bending radius in the range 0.75 to 1.25m) solenoids (e.g., 2 T, 30 cm inside diameter) with superimposed dipole fields (e.g., 1 T) for dispersion generation in large emittance beams; (5) improved industrial fabrication methods for magnets such as welding and forming; (6) improved cryostat and cryogenic techniques; or (7) fast cycling HTS magnets capable of operation at or above 4T/s.

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Contact: Bruce Strauss, 301-903-3705, bruce.strauss@science.doe.gov

64c. Starting Raw materials and Basic Superconducting Materials
High performance niobium-titanium (Nb-Ti) alloys operating above 8 T continue to be required for focusing quadrupole magnets or for graded windings in the low-field portions of high-field magnets. Therefore, grant applications are sought to develop Nb-Ti composite superconductors with properties optimized at 8 T fields and higher at 4.2 K.

Present wires made of magnesium diboride (MgB_2) and its alloyed variants are characterized by a filling factor that is too low, wire cross-sections that have too few filaments, and upper critical and irreversibility fields that are too low. Therefore, grant applications should seek to improve the current density over the wire cross-section, implement restacked round-wire multi-filamentary designs, and extend the field at which a critical current density can be attained over the superconductor cross-section of 1200 A mm^{-2} in the 12-16 T range at 4.2 K.

Lastly, grant applications are sought to develop (1) A-15 compounds, such as Nb_3Sn and Nb_3Al – a minimum current density of 1800 A mm^{-2} at 15 T and 4.2 K must be achieved in the superconductor itself; and (2) high-temperature superconductors (HTS), such as $Bi_2Sr_2CaCu_2O_8$ and $YBa_2Cu_3O_{7-\delta}$ – a minimum current density of 1200 A mm^{-2} (not A cm^{-2}) must be achieved in the superconductor itself, and a minimum current density of 250 A mm^{-2} must be achieved over the total conductor cross section at 12 T minimum and 4.2 K.

Contact: Bruce Strauss, 301-903-3705, bruce.strauss@science.doe.gov

64d. Ancillary Technologies for Superconductors
Grant applications also are sought to develop innovative wire and cable design and processing technologies. Approaches of interest include methods to utilize stranded conductors with high aspect ratio, such as Rutherford cables, or low-loss tape geometries in particle accelerator applications; and technologies to improve wire piece length and increase billet mass.

Grant applications also are sought for innovative insulating materials that are compatible with the use of inter-metallic superconductors in practical devices. Approaches of interest should enable the use of inter-metallic superconductors (such as the A-15, HTS, or MgB_2 types) in practical devices. Insulating systems must be compatible with high temperature reactions in the 750-900 ºC range, be capable of supporting high mechanical loads at both room and cryogenic temperatures, have a high coefficient of thermal conductivity, be resistant to radiation damage, and exhibit low creep and low out-gassing rates when irradiated.

Lastly, grant applications are sought to develop HTS conductors suitable for the very-high-field 30-50 T solenoids needed for final ionization cooling stages of a Muon Collider.

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Contact: Bruce Strauss, 301-903-3705, bruce.strauss@science.doe.gov

64e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Bruce Strauss, 301-903-3705, bruce.strauss@science.doe.gov

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65. ACCELERATOR TECHNOLOGY FOR THE INTERNATIONAL LINEAR COLLIDER

The DOE High Energy Physics (HEP) program supports research and development for the International Linear Collider (ILC), a 500-1000 GeV superconducting linear electron-positron collider, that will probe the energy frontier with unprecedented precision (see reference 1). Grant applications submitted in response to this topic must explicitly describe the relevance of the proposed technology to the ILC. Proposed approaches must demonstrate an awareness of ILC linac parameters, which include a beam intensity of $2x10^{10}$ electrons or positrons per bunch, in trains of about 3000 bunches, separated by about 300 ns. The trains themselves occur at a repetition rate of 5 Hz. Each bunch has an rms invariant transverse emittance of about 8 µm (horizontal) by 0.02 µm (vertical), with an rms bunch length of 300 µm. Beam size at the interaction point (IP) is about 6 nm vertically. The energy varies from 5 GeV at the start of the linac to 250 GeV at the end.

Grant applications are sought in the following subtopics.

65a. Superconducting Radiofrequency Cavities

Grant applications are sought to develop high gradient, 1.3 GHz superconducting RF cavities, with application to the accelerating structures needed for the ILC. Multi-cell cavities that can be reproducibly fabricated with accelerating gradients greater than 35 MV/m and *Q*-factors greater than $5x10^9$ are of interest. Priority areas of research focus include new cavity geometries, improved control of field emission, and suppression of high-field *Q*-slope. Of particular interest are research areas and fabrication techniques that hold promise of significant cost reduction for the production of SRF cavities. .

Grant applications also are sought to develop SRF cavity processing technology to clean and improve the smoothness of the surface of multi-cell niobium (Nb) cavities. Priority approaches include: innovative chemical and electropolishing routes, especially those that reduce or eliminate the dependence on hydrofluoric acid; in-line diagnoses of process acids for ion content and dissolved metal; alternative routes such as tumbling, plasma cleaning, or ion bombardment; quality assurance, control, and testing technologies; and advanced cleaning and handling techniques to eliminate particulate contamination as a source of field emission in the cavities. Proposed processing technologies should be able to demonstrate an improvement in the accelerating gradient of the cavities, compared to present baseline techniques, at an equivalent or reduced cost of implementation.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65b. Instrumentation for SRF Cavities

Grant applications are sought for technology to support the development of fundamental power couplers and tuners for 1.3 GHz SRF cavities. Areas of interest include improvements to current coupler design (resulting in reduced conditioning time, reduced cost, and improved reliability); new tuner designs and concepts for both fast and slow tuning; and inexpensive, broad-band, 2K microwave absorbing material with repeatable electrical properties for high order mode (HOM) damping and resonance suppression.

Grant applications also are sought to develop digital, low-level RF (LLRF) systems to control the phase and amplitude of SRF cavities operating at 1.3 GHz, with loaded *Q*-values in the range of 10^6. Of particular interest are systems capable of phase control at the level 0.5^o or better, and amplitude control at the level of 0.1% or better. Advanced LLRF systems that can perform vector sum control on ILC cryomodules, thus allowing each cavity to be run at its full potential, are also of interest.

Lastly, grant applications are sought to develop instrumentation that can be used to monitor x-rays caused by electron field emission in SRF cavities. Proposed systems should support mapping of radiation from ILC-type cavities during testing in vertical and horizontal test dewars. Sensors must be operable in liquid Helium at temperatures down to ~1.5 K. The objective is to determine the location(s) of the field emitters. Tomographic techniques may be applicable.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65c. High Power RF Sources

Grant applications also are sought to develop high efficiency 1.3 GHz modulators and klystrons, capable of operation at peak power levels on the order of 10 MW, with a pulse width of 1-3 ms, at a repetition rate of 5-10 Hz. The modulator efficiency should be greater than 75%, and the klystron efficiency should be greater than 65%. Of greatest interest are modulator designs with a small physical footprint, a high reliability, and the capability to deliver high voltage pulses suitable for direct coupling to the klystron. Grant applications also are sought to develop power distribution systems suitable for the transport of L-band microwave power at the level of 10 MW (peak) and to develop components (such as RF bends and tap-offs) for use in the 350 MW Klystron Cluster Scheme that is being developed for ILC. Additional ILC parameters can be found in the introduction to this topic.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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65d. Cryogenic and Refrigeration Technology for SRF Systems
The ILC is based on the cold (superconducting) technology requiring a large cryogenic system. Grant applications are sought for research and development leading to the design and fabrication of ILC cryomodules for 1.3 GHz superconducting cavity strings. Each ILC cryomodule contains eight or nine1.3 GHz cavities and couplers in its He vessels, quadrupoles, tuners, and 2K helium distribution system. Therefore, improvements in cryomodule design and fabrication, which result in lower costs, are of particular interest.

Grant applications also are sought to increase the technical refrigeration efficiency – from 20% Carnot to 30% Carnot – for large systems (e.g. 10 kW at 2K), while maintaining higher efficiency over a capacity turndown of up to 50%. This might be done, for example, by reducing the number of compression stages or by improving the efficiency of stages. Grant applications also are sought to develop improved and highly efficient liquid helium distribution systems.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65e. Beam Instrumentation and Feedback Systems

Grant applications are sought to develop:

(1) fast transverse feedback systems, appropriate for controlling vertical beam jitter at the 0.1 sigma level, in linear colliders with long bunch trains (on the order of 1 ms). Areas of particular interest include systems with bandwidth sufficient to control single bunches within a train (with a bunch separation of order 100 ns), and systems that can operate on a train-by-train basis (with a train repetition period of order 5 Hz). System design should be based on the bunch parameters of the ILC, which are listed in the introduction to this topic.

(2) large aperture (> 70 mm diameter) linac beam position monitoring systems, capable of single-bunch position resolution of 1 µm (rms) or better. High precision beam position monitors for the damping rings and beam delivery system are also of interest. The system design must be relevant for the bunch parameters of the ILC, which are listed in the introduction to this topic.

(3) high resolution beam profile monitoring systems capable of measuring the emittance of a high energy electron/positron beam, with the bunch parameters of the ILC, which are listed in the introduction to this topic. The emittance should be measured with an accuracy of 10% or better.

(4) particle beam technologies to facilitate the installation, support, and alignment of very large accelerator beam line lattice elements.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65f. Undulators
The ILC uses undulators to generate the photons that subsequently impinge on a thin target to produce positrons. Grant applications are sought to develop short-period helical undulators, suitable for use with a high-energy (>150 GeV) electron beam, to produce an intense 10 MeV

photon beam. The undulator field, gap, and period must be consistent with the requirements of the ILC undulator-based source (reference 2). ILC parameters are listed in the introduction to this topic.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65g. Magnet and Fast Kicker Technology

Advanced magnet and fast kicker technologies are needed to support the development of the ILC. Accordingly, grant applications are sought to develop:

(1) wiggler systems suitable for use in the damping rings of the ILC. Both permanent magnet and superconducting magnet systems are of interest. Over one damping time, the uniformity of the wiggler field must be sufficient to provide a dynamic aperture of approximately 10 sigma, as determined by tracking particles characteristic of the injected positron beam. The wiggler physical aperture must provide an acceptance of approximately 5 sigma.

(2) fast kicker systems useful for single bunch injection/extraction systems in the ILC damping rings. The rise and fall time of the field seen by the beam must be close to ~1 ns. The overall system (possibly consisting of a number of kicker modules) should be capable of delivering a 0.6 mrad kick to a 5 GeV electron beam. The kicker should be capable of burst operation at 6 MHz for a duration of up to 1 ms, at a repetition rate of 5 Hz.

(4) quadrupole focusing systems, capable of achieving the demagnification needed at the interaction point of the ILC, while satisfying the geometry constraints imposed by the beam crossing angle and the particle detectors (reference 3).

(5) water cooled accelerator magnets with extremely high reliability, characterized by a mean time to failure greater than 10 million hours. These accelerator magnets also require highly reliable power supply systems with a mean time to failure greater than 4 million hours, and high-reliability electronic control systems for magnet operation.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65h. Polarized RF Photocathode Sources

Grant applications are sought for the development of polarized electron sources that operate with RF guns and, consequently, can provide very low emittance beams. The cathode material should have long lifetime and high quantum efficiency, with electron polarization greater than 85%, and an rms invariant emittance of 4π mm-mrad or less. The bunch parameters and format should be those of the ILC, which can be found in the introduction to this topic.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

65i. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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66. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The DOE High Energy Physics (HEP) 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. As high energy physics facilities get bigger and more costly, the DOE HEP program seeks to develop advanced technologies that can be used to reduce the overall machine size and cost.

Grant applications are sought in the following subtopics:

66a. Advanced Accelerator Concepts and Modeling

Grant applications are sought to develop new or improved accelerator designs that can provide very high gradient (>200 MV/m for electrons or >10 MV/m for protons) acceleration of intense bunches of particles, or efficient acceleration of intense (>50 mA) low energy (of order <20 MeV) proton beams. Approaches of interest include: (1) the fabrication of accelerator structures from materials such as Si or SiO_2, using integrated circuit technology, where the realization might include photonic bandgap structures powered by lasers in the wavelength range 1 to 2.5 µm; (2) the development of microcapilllary arrays with arbitrary thickness-to-diameter ratios, with capillary diameters down to 5 microns, and with different diameters and materials in the same plate (which might also incorporate defect structures such as lines and holes); and (3) the development of high-efficiency, high-power, fiber drive lasers at longer wavelengths comparable to what has been achieved for Yb doped silica fiber, but based on other dopants (e.g. Ho, Tm or Cr) and host materials (e.g. phosphate glass). For all proposed concepts, stageability, beam stability, manufacturability, and high-wall plug-to-beam power efficiency should be considered.

Grant applications also are sought to demonstrate proton acceleration in the energy range of 5-25 GeV using non-scaling, fixed-field alternating-gradient (FFAG) accelerators. This demonstration may require an electron model to directly simulate operation in a space-charge limited regime and fast RF modulation for high repetition rate. The HEP application of interest is for a proton driver injector for a neutrino factory. Other possible applications include high-intensity proton drivers for neutron production, waste transmutation, energy production in sub-critical nuclear reactors, medical proton therapy (250 MeV), and radioisotope production.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66b. Technology for Muon Colliders and Muon Beams

Grant applications are sought for the development of novel devices and instrumentation for use in producing intense low energy muon beams suitable for precision muon experiments, and intense high energy muon beams suitable for neutrino factories and/or muon colliders. Approaches of interest include the development of: (1) new concepts for the generation, capture, acceleration, and colliding of intense muon beams; (2) concepts or devices for ionization cooling, including emittance exchange processes; (3) improved simulation packages for studying ionization cooling of muon beams; (4) novel cooling schemes of optical stochastic cooling, coherent electron cooling, and paramteric ionization cooling; (5) concepts or devices for manipulation and control of the longitudinal phase space of large emittance muon beams, including bunching, phase rotation, and bunch merging; (6) concepts or devices for producing intense polarized muon beams; (7) large aperture kickers for injection and extraction in muon cooling rings; (8) concepts and prototyping elements for cost effective rapid acceleration, e.g., 1 T/s pulsed magnets; (9) instrumentation for muon cooling channels that have muon intensities of 10^{12} muons/pulse; or (10) fast (on the order of 10 picosecond) timing detectors for muon cooling experiments with low muon intensity (on the order of 10^5 muons/second).

Grant applications are also sought to develop non-scaling Fixed Field Alternating Gradient (FFAG) and Recirculating Linear Accelerator (RLA) systems for muon acceleration.

For FFAG, approaches of interest include: (1) the development and analysis of FFAG designs that contain insertion sections, (2) engineering design and cost analysis of injection and extraction systems for a neutrino factory FFAG, including the effect of the kicker system on the beam dynamics, and (3) detailed analysis of the dynamics of recently proposed non-scaling FFAG designs, including such features as dynamic aperture (and how it depends on acceleration rate) and sensitivity to errors.

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For RLA, approaches of interest include: (1) lattice optimization for a large energy range, (2) examination of the practical upper limit to the number of passes the beam can make through an RLA, and (3) detailed design of a suitable switchyard and its magnets.

Lastly, grant applications are sought for new concepts, approaches, or designs for radio-frequency amplifiers, or pulse compression schemes, for use in the acceleration and ionization cooling channels of a future muon collider. The amplifiers or compressors must have high peak power (>30 MW) and pulsed, low frequency (from 2 ms pulses at 20 MHz to 0.1 ms pulses at 200 MHz). Higher power (>100 MW) pulsed sources at higher frequencies, e.g., 30 μs at 400 MHz, also are of interest. All muon collider amplifiers must have moderate repetition rate capability (e.g., 50 Hz). Grant applications should address the cost per unit of peak power, including the cost of required power supplies.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66c. Novel Device and Instrumentation Development

Grant applications are sought for the development of electromagnetic, permanent magnet, silicon microcircuit, or electron-beam-based charged particle optical elements for particle beam focusing. Examples include, but are not limited to, (1) dipoles, quadrupoles, higher order multipole correctors for use in electron linear accelerators; and (2) solenoids for use in electron-beam or ion-beam sources, or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.7 to 10 cm. In these optical elements, permanent magnets or hybrid magnets incorporating magnetic materials that have very high residual magnetization, radiation resistance, and thermal stability (low variation of field strength with temperature) are of particular interest.

Grant applications also are sought to develop (1) undulators for bunching high energy electron beams, needed for phased injection in high frequency accelerating structures and for generating coherent transition radiation; (2) electron lenses for compensation of space-charge and beam-beam effects and for particle collimation; (3) novel charged particle beam monitors to measure the transverse or longitudinal charge distribution, emittance, or phase-space distributions of small radius (0.1 μm to 5 mm diameter), short length (10 μm to 10 mm) relativistic electron or ion beams; and (4) devices capable of measuring and recording the Schottky or transition radiation spectrum of these beams (proposed techniques should be nondestructive, or minimally perturbative, to the beams monitored and have computer-compatible readouts).

Grant applications also are sought to develop achromatic, isochronous compact focusing systems with broad energy acceptance and compact broadband (10-100 MeV) spectrometers, suitable for use in laser acceleration experiments.

Lastly, grant applications are sought to develop high density (range of 10^{18}-10^{20} cm^{-3}), high repetition rate (≥10 Hz) pulsed gas jets, capable of producing longitudinally tailored density profiles with long lengths (centimeter scale) and narrow widths (few hundred microns) for use in laser wakefield accelerators. The gas jet should have sharp entrance gradients, with a transition region/length on the order of 500 μm. The pulse duration of the jets should be less than 500 μs to minimize the amount of gas loading in vacuum chambers. Cluster gas jets, i.e., jets that are cooled and produce atomic clusters, are also of interest.

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Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66d. Laser Technology for Accelerators

Lasers are used in many areas of accelerator applications, ranging from plasma channel formation to laser wakefield acceleration. Grant applications are sought to develop lasers for laser-accelerator applications that provide substantial improvements over currently available lasers in one or more of the following parameters: (1) longer wavelengths (up to 2 to 2.5 μm for use with Si transmissive optics), (2) very short wavelengths (< 200 nm) with low mode numbers (M-squared < 100) and high pulse energy (> 0.1 J) for photo-ionized plasma sources, (3) higher power, (4) higher repetition rates, and (5) shorter pulse widths.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66e. Inexpensive High Quality Electron Sources

Grant applications are sought for the design and prototype fabrication of small, inexpensive electron sources for use in advanced accelerator R&D laboratory experiments. The following parameters are target values for accelerator research experiments: (1) energy range of 5 to 35 MeV providing, at a minimum, on the order of 10^9 electrons in a bunch less than 5 picoseconds long; (2) normalized transverse beam emittance $<5\pi$ mm-mrad; and (3) pulse repetition rate >10 Hz. Grant applications also are sought for sources with significantly lower bunch charges, energies, and emittances from a matrix cathode, but at comparable or greater peak currents and significantly higher repetition rates. In addition, grant applications are sought to develop a bright direct-current/radio-frequency (DC/RF) photocathode electron source that combines a pulsed high-electric-field DC gun and a high field RF accelerator, operates at a repetition rate of several kHz, and has electron bunch specifications similar to those listed above.

Grant applications also are sought to develop: (1) robust RF photocathodes (quantum efficiencies >0.1 percent) or other novel RF gun technologies operating at output electron beam energies >3 MeV; (2) laser or electron driven systems for such guns; and (3) electron beam sources, such as sheet or multiple beams, relevant to the abovementioned high power RF applications.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66f. Hardware and Software Solutions for Accelerator Control

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

Grant applications also are sought to develop real-time optical networks for pulsed-accelerator control. These networks require timing information to be combined with data-communication functions on a single optical fiber connected to pulsed device-controllers. The single fiber should provide each controller with an RF-synchronized clock that has the following features: (1) an arrival time that is phase-locked to the temperature-stabilized RF reference phase, (2) a phase-locked machine pulse fiducial point, (3) digital data for machine pulse-type selection and specific pulse identification, and (4) real-time-streaming pulsed waveform data-acquisition capabilities. The controllers serve as interfaces to systems that provide such functions as low-level RF signal generation, modulator control, beam position monitors, and machine protection system sensing. The network should provide real-time, fast-feedback loop closure and TCP/IP connectivity for slow control functions such as database access, device configuration, and code downloading and debugging.

Finally, grant applications are sought to develop real-time processors and software for pulsed accelerator control and monitoring. The software should be based on a multiprocessor architecture that can be deeply embedded within pulsed device-controllers, which employ system-on-a-chip, field-programmable gate-array, or application-specific integrated circuit technologies. The architectures should feature distinct processors for real-time pulse-to-pulse functions, and conventional slow control functions. Architectural provisions for supporting machine protection functions via an additional processor or dedicated hardware also should be included.

For the preceding two paragraphs, proposed solutions should be engineered to include: (1) resistance to electromagnetic interference generated by nearby, large pulsed-power systems; and (2) maximum availability in remote deployment locations.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66g. Computational Tools and Simulation of Accelerator Systems

Grant applications are sought to develop new or improved computational tools for the design, study, or operation of charged-particle-beam optical systems, accelerator systems, or accelerator components. These tools should incorporate innovative user-friendly interfaces, with emphasis on graphical user interfaces and windows. Grant applications also are sought for the conversion of existing codes for the incorporation of these interfaces (provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate).

Grant applications also are sought to develop improved simulation packages for injectors or photoinjectors. Areas of interest include: (1) improved space-charge algorithms; (2) improved algorithms for the self-consistent computation of the effects of wakefields and coherent synchrotron radiation on the detailed beam dynamics; (3) improved fully-three-dimensional algorithms for the modeling of transversely asymmetric beams; and (4) explicit end-to-end simulations that provide for more accurate beam-quality calculations in full injector systems.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

66h. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

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Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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

Radio frequency (RF) technology is a key technology common to all high energy accelerators. RF sources with improved efficiency and accelerating structures with increased accelerating gradient are important for keeping the cost down for future machines. Relevance to applications in HEP must be explicitly described.

Grant applications are sought in the following subtopics.

67a. New Concepts and Modeling Techniques for 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 >150 MV/m for electrons and >10 MV/m for protons in normal cavities are of particular interest, as are means for suppressing unwanted higher-order modes and reducing costs. In muon accelerator R&D, structures for capture and acceleration of large emittance muon beams and techniques for achieving gradients of 5-20 MV/m in cavities with frequencies between 5 and 400 MHz (including superconducting cavities whose resonant frequencies can be rapidly modulated) are of interest. Methods for reducing surface breakdown and multipactoring (such as spark-resistant materials or surface coatings, or special geometries) and for suppressing unwanted higher order modes also are of interest, as are studies of surface breakdown and its dependence on magnetic field. Grant applications should be applicable to devices operating at frequencies from 1 to 40 GHz, or between 5 and 400 MHz for muon accelerators.

Grant applications also are sought to develop simulation tools for modeling high-gradient structures, in order to predict such experimental phenomena as the onset of breakdown, post breakdown phenomena, and the damage threshold. Specific areas of interest include the modeling of: (1) surface emission, (2) material heating due to electron and ion bombardment, (3) multipactoring, and (4) ionization of atomic and molecular species. Approaches that include an ability to import/export CAD descriptions, a friendly graphical user interface, and good data visualization will be a plus.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67b. Materials and Fabrication Technologies for SRF Cavities

Material properties, surface dynamics, processing procedures, and geometric configurations can have significant impact on the performance of the accelerator cavities. Grant applications are sought to develop (1) new materials that are suitable for the fabrication of superconducting radiofrequency (SRF) cavities, such as large grain or single crystal Nb; (2) new or improved SRF cavity fabrication techniques especially weld-free approaches, and (3) improved understanding and performance of SRF cavities.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67c. Radio Frequency Power Sources and Components

Grant applications are sought to develop new concepts, high-power RF components, and instrumentation for use in producing high peak power in narrow-band, low-duty-cycle, and low-pulse-repetition-frequency (approximately 100 Hz) pulsed X-band RF amplifiers. The principal application will be for future large multi-TeV electron/positron linear colliders. Of particular interest are innovations related to cost saving, manufacturability, and electrical efficiency. Also of interest are RF sources for high-gradient accelerator research. Innovations that allow the source to be configured for different frequencies at low cost are of particular interest.

The next generation of multi-TeV linear colliders will require many RF power handling components which have not been fully developed, e.g., RF windows, couplers, mode transformers, RF loads, and high power rings capable of operating at high pulse powers. Consequently, grant applications are sought to develop active or passive RF pulse compression systems capable of handling high peak powers (for example, greater than 300 MW) and pulse widths of approximately 300 nanoseconds at X-band. Grant applications also are sought for passive and active RF components such as over-moded mode converters (e.g., rectangular to circular waveguide and vice versa), high-power RF windows, circulators, isolators, switches, and quasi-optical components.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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67d. Modulators for Pulsed Radio Frequency Systems

Most RF power sources for future linear colliders require high peak-power pulse modulators of considerably higher efficiency than presently available. Grant applications are sought for new types of modulators in the 100 kV – 1 MV range for driving currents of 0.1 – 1 kA, with pulse lengths of 0.2 – 5.0 μs, and with rise- and fall-times that are ~10% of the pulse length or less. Grant applications also are sought for the development of modulators with improved voltage control for RF phase stability in some alternate RF power systems, as well as cathode modulators that are compact and cost competitive compared to present cathode pulse modulator schemes. Grant applications should address issues related to cost saving, manufacturability, and electrical efficiency in modulators.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67e. Switching Technology for Pulsed Power Applications

Existing Insulated Gate Bipolar Transistor (IGBT) packages for high voltage and high pulsed current (e.g., V = 6.5 kV, I = 3 kA peak, 800 A average) are not optimized for very high speed pulsed power applications (10 MW peak for 3.2 μs at 120 Hz) due to failure modes induced by very rapid fall times (di/dt >10 kA/μs) and/or rise times (dV/dt >15 kV/μs) upon device turn-off. Therefore, grant applications are sought to reduce these failure modes through improved packaging of commercial IGBT chips, by incorporating appropriate protective circuitry in a high voltage power package designed specifically for high-speed transients.

Grant applications are sought to develop improved high power solid-state switches for pulse power switching. For some applications, requirements will include the ability to switch high current pulses (0.1-10 kA) at voltage levels of up to 20 kV, with switching times less than 300 nsec. These switches must handle very high di/dt (20 kA/μs) at low duty cycle (<0.1%).

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67f. Energy Storage for Pulsed Power Systems

High reliability, high-energy-density energy storage capacitors are a key component for the development of reliable solid state pulsed power systems. Grant applications are sought to develop and optimize storage capacitors that can: (1) deliver high peak pulse current (0.1-10 kA) in the partial discharge region (less than 30 percent voltage droop during pulse); (2) be designed with very low inductance connections to allow fast rise and fall time discharge without ringing (di/dt ~20 kA/μs); (3) be packaged to meet the requirements of high power solid state board layouts and have minimum production cost; and (4) have an accurately known lifetime of tens of thousands of hours.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67g. Deflecting Cavities (AKA "crab cavities") for Luminosity Enhancement in Colliders

High luminosity colliders can benefit from the use of a crossing angle between the colliding beams. The crossing angle will provide a larger luminosity gain if the particle bunches are tilted, resulting in what is called a "crab crossing." Grant applications are sought for the development of crab cavities for the LHC and for the ILC. Approaches of interest, which may include new cavity geometries, should include the demonstration of high-performance prototype superconducting crab cavities. Grant applications also are sought for ancillary technology for use with crab cavities, including the development of (1) fundamental power couplers; (2) high-order, same-order, and low-order mode damping couplers, including design, analysis, and low-power testing; and (3) conceptual and detailed designs for low-cost crab cavity cryomodules and tuners.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

67h. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: LK Len, 301-903-3233, lk.len@science.doe.gov

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68. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. Further information about research funded by the Office of Fusion Energy Sciences (OFES) can be found at the OFES Website (URL: www.ofes.fusion.doe.gov).

Grant applications are sought in the following subtopics:

68a. Plasma Facing Components

The plasma facing components (PFCs) in energy producing fusion devices will experience 5-15 MW/m^2 surface heat flux under normal operation (steady-state) and off-normal energy deposition up to 1 MJ/m^2 within 0.1 to 1.0 ms. Refractory solid surfaces represent one type of PFC option. These PFCs are envisioned to have a refractory metal heat sink, cooled by helium

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gas, and a plasma facing surface, consisting of an engineered refractory metal surface or a thin coating of refractory material that minimizes thermal stresses. The materials being considered include tungsten and molybdenum alloys. Grant applications are sought to develop: (1) innovative refractory alloys having good thermal conductivity (similar to Mo, at a minimum), resistance to recrystallization and grain growth, good mechanical properties (e.g., strength and ductility), and resistance to thermal fatigue; (2) coatings or specialized low-Z surface treatments of refractory alloy armor for improved plasma performance; (3) innovative refractory-metal heat sink designs for enhanced helium gas cooling; (4) efficient fabrication methods for engineered surfaces that mitigate the stresses due to high heat flux; and (5) joining methods, for attaching the plasma facing material to the heat sink, that are reliable, efficient to manufacture, and capable of high heat transfer – these new joining techniques may be applicable to either advanced, helium-cooled, refractory heat sinks or present-day, water-cooled, copper-alloy heat sinks.

In addition, grant applications are sought to develop new or improved *in situ* diagnostic techniques to monitor the health and performance of operating PFCs and plasma edge conditions. A carefully selected combination of microelectromechanical (MEMS)-like, robust diagnostics could create an instrumented PFC that monitors important characteristics (such as the temperature and stress gradients) within the PFC or provides real-time information on erosion/deposition rates or tritium uptake during operation. Measurements of current, B-field, plasma edge temperature and density, spectral emissions, and heat flux also would be of interest. Such diagnostics must be an integral part of the PFC, be self-powered, operate at elevated temperatures in the presence of high magnetic fields and neutron fluence, be immune to RF noise, provide for wireless data transmission with high signal to noise ratio, and be compatible with high performance plasma operation.

Another PFC option is to use a flowing liquid metal surface as a plasma facing component, an approach which will require the production and control of thin, fast flowing, renewable films of liquid lithium, gallium, or tin for particle control at divertors. Grant applications are sought to develop: (1) techniques for the production, control, and removal of flowing (velocity 0.01 to 10 m/s) liquid metal films (0.5-5 mm thick) over a temperature controlled substrate; (2) advances in materials that are wet by liquid metals at temperatures near the respective metal melting point and that are conducive to the production of uniform well-adhered films; (3) techniques for active control of liquid metal flow and stabilization in the presence of plasma instabilities (time and space varying magnetic field); and (4) computational tools that model the flow and magnetohydrodynamic response of flowing liquid metals.

Grant applications also are sought to develop and demonstrate innovative computational techniques directly related to modeling surface material properties and/or plasma surface/interactions, for the purpose designing and assessing PFC surface materials. Finally grant applications are sought to develop cost-effective experimental techniques that integrate multiple approaches, listed in the paragraphs above, in order to allow advanced plasma-material-interaction testing and simulation.

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

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68b. Blanket Materials and Systems

Blanket systems including an integrated first wall facing the plasma are complex, multi-function, multi-material components that capture neutrons emitted from the burning plasma to both produce tritium via nuclear reactions with lithium, and extract the energy for efficient power conversion. Associated with the blanket are coolant and tritium processing systems, all of which have scientific and technological issues in need of resolution. Proposals that address these issues in areas such as:

- thermofluid and thermomechanical simulation of coolant flows and structural responses under surface and volumetric heat loads;
- mass transport (corrosion and tritium) modeling development and simulations;
- ceramic breeder and beryllium pebbles material fabrication, characterization, and thermomechanics;
- SiC or alternate insulators for electric current and thermal heat;
- tritium permeation barriers and permeator windows, corrosion barriers, etc.;
- chemistry and impurity control in coolants (helium, liquid metals, etc.);
- Flow and other diagnostic sensors compatible with fusion environment; or any blanket and tritium system relevant development issue.

Several areas of particular interest are described in more detail below.

There is a strong need to understand and predict in greater detail both the corrosion, transport and redoposition of materials, and the generation, bubble formation, transport and permeation of tritium in the fusion relevant coolant and breeder material Pb-15.7Li alloy. Both numerical predictive tools and increased database from experimental studies are needed to better characterize the corrosion and tritium transport behavior in Pb-Li alloy under fusion relevant conditions that include operation at 400-700C and the presences of strong magnetic fields in contact with various materials such as ferritic steels, silicon-carbide, and other proposed tritium or corrosion barrier or permeator materials for tritium extraction.

The pebble-bed solid breeder configuration introduces several operational limits: thermo-mechanical uncertainties caused by pebble-bed wall interaction, potential sintering and subsequent macro-cracking, and a low pebble-bed thermal conductivity – all of which result in small characteristic bed dimensions and limit windows of operation. A new form of solid breeder morphology is required that holds the promise for increased breeding ratios – dictated by increased breeder material density; long term structural reliability; and enhanced operational control – compared to packed beds. Grant applications are sought for new solid breeder material concepts that include: (1) increased breeder material densities (~80%); (2) higher thermal conductivities (provided by a fully interconnected structure, as opposed to point contacts between pebbles); (3) better thermal contact, such as reliable bonded contact, with cooling structures (instead of point contacts between pebbles and wall); (4) the absence of major geometry changes between beginning-of-life and end-of life (such as sintering in pebble beds) in the presence of high neutron fluence; and (5) structural integrity in freestanding and self-supporting structures with significant thermo-mechanical flexibility.

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Flow channel inserts (FCIs) act as magnetohydrodynamic and thermal insulators in ferritic steel channels containing, for example, a slowly flowing tritium breeder such as molten Pb-15.7Li alloy. The insert geometry is approximately box-channel-shaped in straight channels, with more complex shapes possible, for insertion in manifolds and other complex-geometry elements in the flow path. Although SiC/SiC composite is a candidate FCI material, its use would differ from its potential application as a structural material in that high thermal and electrical conductivity would not be desirable. In fact, the electrical conductivity should be low, with a target maximum around 1 to 50 $\Omega^{-1}m^{-1}$. In addition, the strength requirements for a SiC/SiC FCI are reduced compared to the composite's application as a structural material, because the primary stresses and pressure loads will be very low. On the other hand, the insert must be able to withstand thermal stresses from through-surface temperature differences in the range of 150-300K, over a thickness of 3 to 15 mm depending on designs. Grant applications are sought to develop manufacturing techniques for radiation resistant, low thermal/electrical conductivity SiC/SiC composites or other suitable, compatible materials that would make for effective FCIs. One approach that has been envisioned is the use of a final "sealing" layer of SiC matrix material, which would be near theoretical density and cover any porosity or exposed fibers in the main body of the insert. Two-dimensional weaves are also thought to be satisfactory, as well as an effective way to reduce electrical conductivity normal to the interface between the insert and the Pb-15.7Li (the more important of the directions). In addition, grant applications are sought to develop experimental techniques for determining: (1) the compatibility between the SiC/SiC composite and such breeder materials as Pb-15.7Li alloy, and (2) the insert integrity under cyclic thermal loading and other in-service conditions.

One of the missions of the ITER project is the integrated testing of fusion blanket modules in a true integrated fusion environment. This ITER fusion environment includes radiation and magnetic fields, along with surface and volumetric heating, under pulsed and/or steady-state plasma operation. The testing of first wall/blanket components will be performed in ITER by inserting "test blanket modules" (TBMs) that will be complicated systems of different functional materials (breeder, multiplier, coolant, structure, insulator, etc.) in various configurations with many responses and interacting phenomena (e.g., thermomechanical, thermofluid, nuclear). As part of the design and validation process an overall simulation of a "virtual" TBM, integrating all of the individual computational modeling simulations at the system level, is essential to define meaningful experiments. Such a simulation would be inherently multi-scale and multi-physics and will require careful code and algorithm design. Therefore, grant applications are sought to develop a TBM and general power reactor relevant simulation code that can provide detailed predictions of: (1) fluid flow and thermal hydraulic characteristics; (2) the thermal response of all materials (structure, breeder, multiplier, coolant, insulator, etc); (3) structural responses such as stress and deformation magnitudes with respect to different loadings, including both steady-state surface heat flux and dynamic loadings; (4) mass transfer characteristics including both corrosion and tritium transport phenomena, and (5) other important performance characteristics of the TBM or blanket system. The overall code framework/structure must effectively link all of the simulation components of the virtual TBM and serve as an efficient, useful, and user-friendly tool that is extendable from ITER to demonstration power reactor conditions.

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

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68c. Superconducting Magnets and Materials
New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems. Of particular interest are magnet components, superconducting, structural and insulating materials, or diagnostic systems that lead to magnetic confinement devices which operate at higher magnetic fields (14T-20T), in higher nuclear irradiation environments, provide improved access/maintenance or allow for wider operating ranges in temperature or pulsed magnetic fields.

Grant applications are sought for:

(1) Innovative and advanced superconducting materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs. Of specific interest are materials such YBCO conductors that are easily adaptable to bundling into high current cables carrying 30 - 60 kA. Desirable characteristics include critical currents at temperatures from 4.5 K to 50 K, magnetic fields in the range 5 T to 20 T, higher copper fractions, low transient losses, low sensitivity to strain degradation effects, high radiation resistance, and improved methods for cabling tape conductors taking into account twisting and other methods of transposition to ensure uniform current distribution.

(2) Novel methods for joining coil sections for manufacture of demountable magnets that allow for highly reliable, remakeable joints that exhibit excellent structural integrity, low electrical resistance, low ac losses, and high stability in high magnetic field and pulsed applications. These include conventional lap and butt joints, as well as very high current plate-to-plate joints.

(3) Innovative structural support methods and materials, and magnet cooling and quench protection methods suitable for operation in a fusion radiation environment, that result in high overall current density magnets.

(4) Novel, advanced sensors and instrumentation for monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); of specific interest are fiber optic based devices and systems that allow for electromagnetic noise-immune interrogation of these parameters as well as positional information of the measured parameter within the coil winding pack. A specific use of fiber sensors is for rapid and redundant quench detection. Novel fiber optic sensors may also be used for precision temperature or strain sensing for scientific studies of conductor behavior and code calibration.

(5) Radiation-resistant electrical insulators, e.g., wrapable inorganic insulators and low viscosity organic insulators that exhibit low gas generation under irradiation, less expensive resins and higher pot life; and insulation systems with high bond and higher strength and flexibility in shear.

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

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68d. Structural Materials and Coatings

Fusion materials and structures must function for a long time in a uniquely hostile environment that includes combinations of high temperatures, reactive chemicals, high stresses, and intense damaging radiation. The goal is to establish the feasibility of designing, constructing and operating a fusion power plant with materials and components that meet demanding objectives for safety, performance and minimal environmental impact. Pursuant to this goal grant applications are sought for:

(1) Development of innovative methods for joining beryllium (~2 mm thick layer) to RAFM steels. The resulting bonds must be resistant to the effects of neutron irradiation, exhibit sufficient thermal fatigue resistance, and minimize or prevent the formation of brittle intermetallic phases that could result in coating debonding.

(2) Development of fabrication techniques for typical component geometries envisioned for use in test blanket modules for operation in ITER using current generation RAFM steels. Such fabrication techniques could include but are not limited to appropriate welding, hot-isostatic pressing, hydroforming, and investment casting methods as well as effective post joining heat treatment techniques and procedures. Appropriate fabrication technologies must produce components within dimensional tolerances, while meeting minimum requirements on mechanical and physical properties.

(3) Development of oxide dispersion strengthened (ODS) ferritic steels. Approaches of interest include the development of low cost production techniques, improved isotropy of mechanical properties, development of joining methods that maintain the properties of the ODS steel, and development of improved ODS steels with the capability of operating up to ~800˚C, while maintaining adequate fracture toughness at room temperature and above.

(4) Development of high ductility, high-fracture toughness tungsten alloys with isotropic properties. Areas of interest include improvements in the grain boundary strength and fracture toughness, and joining techniques. In addition, development of engineered tungsten/PFC materials to control or eliminate blistering associated with the interaction of tungsten with He and H isotopes from the plasma by providing high diffusivity paths to release He and H and decrease retention of these gases is of interest.

(5) Development of functional coatings for the RAFM/Pb-Li blanket concept. Coatings are needed for functions that include (1) compatibility: minimizing dissolution of RAFM in Pb-Li at 700°C, (2) permeation: reducing tritium permeation (hydrogen for demonstration) by a factor of >100 and (3) electrically insulating: reducing the pressure drop due to the magneto-hydrodynamic (MHD) effect. Proposed approaches must: (1) account for compatibility with both the coated structural alloy and liquid metal coolant for long-time operation at 500-700˚C (2) address the potential application of candidate coatings on large-scale system components; and (3) demonstrate that the permeation and MHD coatings are functional during or after exposure to Pb-Li.

(6) Development of failure assessment and lifetime prediction methodologies of structural materials in the fusion environment, including physics-based methods to determine damage

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accumulation, residual life, and reliability of structural components under combinations of steady and cyclic loading, high-temperature, and neutron irradiation.

(7) Development of innovative modeling tools for the above joining methods, materials, and coatings. Modeling approaches may range from atomistic and molecular dynamics simulations of atomic collision and defect migration events to improved finite element analysis or thermodynamic stability methods.

Priority will be given to innovative methods or experimental approaches that enhance the ability to obtain key mechanical or physical property data on miniaturized specimens, and to the micromechanics evaluation of deformation and fracture processes.

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

68e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

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69. FUSION SCIENCE AND TECHNOLOGY

The Fusion Energy Sciences program currently supports several fusion-related experiments with many common objectives. These include expanding the scientific understanding of plasma behavior and improving the performance of high temperature plasma for eventual energy production. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts for (a) measuring magnetized-plasma parameters, (b) for low-temperature and multi-phase plasmas, (c) for magnetized-plasma simulation, control, and data analysis, and (d) for overcoming deleterious plasma effects during discharges. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector. Further information about research funded by the Office of Fusion Energy Sciences (FES) can be found in the FES Website **(URL:** http://www.science.doe.gov/ofes/**).**

Grant applications are sought in the following subtopics:

69a. U.S. ITER Diagnostics

The United States has joined the international collaboration to construct and operate ITER, a full-scale experimental fusion energy device that will pave the way to clean energy. In order for U.S. allocated diagnostics systems to better meet the functional measurement requirements for ITER, grant applications are sought to improve some subsystem components. Components of interest include: (1) Faraday isolator for CO_2 (10.6 micron) lasers to eliminate laser instabilities for the ITER tangential interferometer/polarimeter system and the ITER divertor interferometer systems; (2) fiber-optic-based laser endoscope for remote monitoring of optical quality and ablation of coated deposits on diagnostic mirrors; (3) motion-compensating miter bends in overmoded, corrugated microwave waveguide or ITER low-field-side

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reflectometer and electron cyclotron emission system corrugated waveguide transmission systems; (4) low-loss, broadband quasi-optical frequency multiplexers in the 50 to 200 GHz frequency range to combine different X-mode frequency bands (V, W, D, and G) for the low-field-side reflectometer into a single corrugated waveguide; (5) low insertion loss (<3dB), high rejection (> 50dB) microwave notch filter at the ITER electron cyclotron heating (ECH) frequency for the ITER low-field-side reflectometer and electron cyclotron emission systems; (6) robust, reliable mixers and local oscillators (LO) in the 200-300 GHz range for the ITER electron cyclotron emission system corrugated waveguide transmission system; and (7) a specially-packaged sensor array based on single photon/particle counting silicon pixel array detectors (PADS) with an upper-level discriminator for high resolution core imaging x-ray spectrometer. Grant applications must propose the development of hardware for U.S. ITER diagnostics; all other applications will be declined.

Contact: Nirmol Podder, 301-903-9536, nirmol.podder@science.doe.gov

69b. Components for Heating and Fueling of Fusion Plasmas

Grant applications are sought to develop components related to the generation, transmission, and launching of high power electromagnetic waves in the frequency ranges of Ion Cyclotron Resonance Heating (ICRH, 50 to 300 MHz), Lower Hybrid Heating (LHH, 2 to 10 GHz), and Electron Cyclotron Resonance (or Electron Bernstein Wave) Heating (ECRH / EBW, 28 to 300 GHz). These improved components are sought for the microwave heating systems of the current large facilities in the United States (Alcator C-Mod, DIII-D and NSTX), facilities under construction (including ITER), and smaller machines exploring innovative and alternate concepts. Components of interests include power supplies, high power microwave sources or generators, fault protection devices, transmission line components, and antenna and launching systems. Specific examples of some of the components that are needed include tuning and matching systems, unidirectional couplers, circulators, mode convertors, windows, output couplers, loads, energy extraction systems from spent electron beams and particle accelerators, and diagnostics to evaluate the performance of these components. Of particular interest are components that can safely handle a range of frequencies and increased power levels.

For the ITER project, the United States will be supplying the transmission lines for both the ECRH (2 MW/line) system, at a frequency of 170 GHz, and for the ICRH system (6 MW/line), operating in the range of 40 – 60 MHz.. For this project, grant applications are needed for advanced components that are capable of improving the efficiency and power handling capability of the transmission lines, in order to reduce losses and protect the system from overheating, arcing, damage or failure during the required long pulse operation (~3000s). Examples of components needed for the ECRH transmission line include high power loads, low loss miter bends, polarizers, power samplers, windows, switches, and dielectric breaks. For the ITER transmission lines, improved techniques are needed for the mass production of components, in order to reduce cost. Lastly, advanced computer codes are needed to simulate the microwave, thermal, and mechanical components of the transmission lines. Components needed for the ICRH lines include high power loads and reliable tuning/matching components.

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Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

69c. Fusion Plasma Simulation and Data Analysis Tools

The realistic simulation of fusion plasmas is important for the design and evaluation of plasma discharge feedback and control systems; the design, operation, and performance assessment of existing and proposed fusion experiments; the planning of experiments on existing devices; and the interpretation of the experimental data obtained from these experiments. The simulation of fusion plasmas is very challenging because (1) the range of temporal and spatial scales involved is enormous and these scales often overlap, violating the assumption of scale separation; and (2) the nonlinear physical processes that govern the behavior of these plasmas are strongly coupled in the regimes of interest for fusion energy production. Although, in recent years, considerable progress has been made toward the understanding of these processes – including particle, momentum, and energy transport driven by plasma turbulence, macroscopic equilibrium and stability, wave-plasma interactions, energetic particle physics, and the behavior of the edge plasma – there remains a critical need to integrate the various plasma models, in order to develop an integrated predictive simulation capability for magnetically confined plasmas. In addition, efficient computational tools are needed to manage, analyze, and visualize the enormous datasets resulting from large scale fusion simulations and experiments.

Grant applications are sought to develop computer algorithms and tools that are applicable to simulations of magnetically confined plasmas, incorporate an expanded number of plasma features, and integrate multiple physical processes across multiple spatial and temporal scales. Areas of interest include, but are not limited to: (1) algorithms incorporating advanced mathematical techniques; (2) algorithms targeting novel computing architectures, including GPU and hybrid computing; (3) multiscale algorithms; (4) verification and validation tools, including efficient methods for facilitating comparison of simulation results with experimental data and the development of synthetic diagnostics; (5) data management, visualization, and analysis tools for local and remote multi-dimensional time-dependent datasets resulting from large scale simulations or experiments; (6) techniques for coupling simulation codes, including coupling across different computer platforms and through high speed networks; (7) methodologies for building highly configurable and modular scientific codes and flexible data interfaces; and (8) remote collaboration tools that enhance the ability of geographically distributed groups of scientists to interact in real-time.

The simulation and data analysis tools should be developed using modern software techniques, should be capable of exploiting the potential of next generation high performance computers, and should be based on high fidelity physics models.

Contact: John Mandrekas, 301-903-0552, john.mandrekas@science.doe.gov

69d. Components and Modeling Support for Innovative Approaches to Fusion

Innovative Confinement Concepts (ICC) is a broad-based, long-range research activity that specifically addresses approaches that could lead to more attractive and practical uses of fusion power. The ICC program also addresses critical scientific issues in magnetic confinement, particularly innovative solutions to problems that hinder the tokamak concept, such as plasma

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disruption, heat load on internal components, and operational and maintenance complexity. ICC research includes investigations in a variety of concepts such as stellarators, spherical tori, and reversed field pinches. It also includes innovative approaches for initiation and increase of plasma current; dissipation of plasma exhaust power; symmetric-torus confinement prediction; stability, continuity, and profile control of low-aspect-ratio symmetric tori; quasi-symmetric and three-dimensional shaping benefits to toroidal confinement performance; divertor design for three-dimensional magnetic confinement configurations; and the plasma-materials interface. Grant applications are sought for scientific and engineering developments, including computational modeling, in support of current experiments in these research activities, in particular for the small-scale concept exploration experiments. Further information on experiments on innovative fusion concepts is available at the FES Website.

Contact: Sam Barish, 301-903-2917, sam.barish@science.doe.gov

69e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Barry Sullivan, 301-903-8438, barry.sullivan@science.doe.gov

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70. HIGH ENERGY DENSITY PLASMAS AND INERTIAL FUSION ENERGY

High energy density plasmas are plasmas with energy densities giving rise to pressures exceeding about 0.1 megabar (10^{10} Pa) and temperature exceeding about 1 eV.

70a. Advancing the Science of High Energy Density Laboratory Plasma

The Department has an interest in producing and developing the science of high-energy-density plasmas and the science involved in inertial fusion energy applications. Research is sought to support on-going activities in laser-driven, pulsed-power-driven, and heavy-ion-driven high-energy-density plasma physics, not including magnetized target fusion but including on-going activities in the areas of ignition pathways and driver options, especially those having a commercial application, in meeting the metrics for practical power generation (minimum capital cost, cost per shot, repetitive operation, maintenance, component lifetime, efficiency, fusion gain, etc).

Contact: Francis Thio, 301-903-4678, francis.thio@science.doe.gov

70b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Francis Thio, 301-903-4678, francis.thio@science.doe.gov

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71. FLYWHEEL ENERGY STORAGE

Flywheels have recently found excellent application in the area of frequency regulation and short term renewable smoothing. Some 60MW of flywheel installation are currently under construction. Further increasing flywheels' applicability for large-scale electricity storage requires improving their energy density. Increasing rotational velocity is the most effective approach for improving energy density because the kinetic energy stored in a flywheel increases in proportion to the *square* of the rotational velocity (*i.e.,* small increases in rotational velocity result in much larger increases in stored energy). Today's high speed flywheels use composite rims that allow faster rotational speeds than earlier steel rims. Composite rims provide the highest energy storage per unit of mass.

71a. Hubless Flywheel Design

Improvements in rim design are expected to be incremental at best because structural limitations prevent large composite wheels from being developed. Specifically, as rotational velocity increases, so does radial force on the rotor (rim/hub assembly), which causes it to expand faster than the shaft. The hub must compensate for this difference in expansion *and* maintain a secure bond with the rim. Currently, the materials properties of the hub are one of the main obstacles to achieving higher rotational velocities. To take a leap forward in flywheel design one of two

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approaches will be necessary to overcome the hub limitations: increase the strength of the hub materials or eliminate the hub. Hubless operation eliminates the central shaft and the hub and, consequently, allows flywheel designers to fully optimize the composite rim. Grant applications are sought to develop hubless flywheel designs. Proposed solutions must be scalable to utility bulk electricity storage systems.

Contact: Imre Gyuk, 202-586-1482, imre.gyuk@hq.doe.gov

71b. Other
In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Contact: Imre Gyuk, 202-586-1482, imre.gyuk@hq.doe.gov

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