DOE/SC-0059
October 15, 2002

SBIR

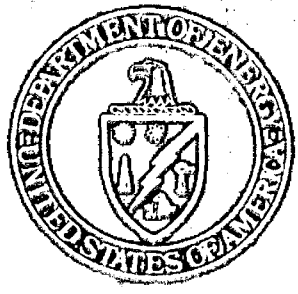
Small Business Innovation Research

STTR

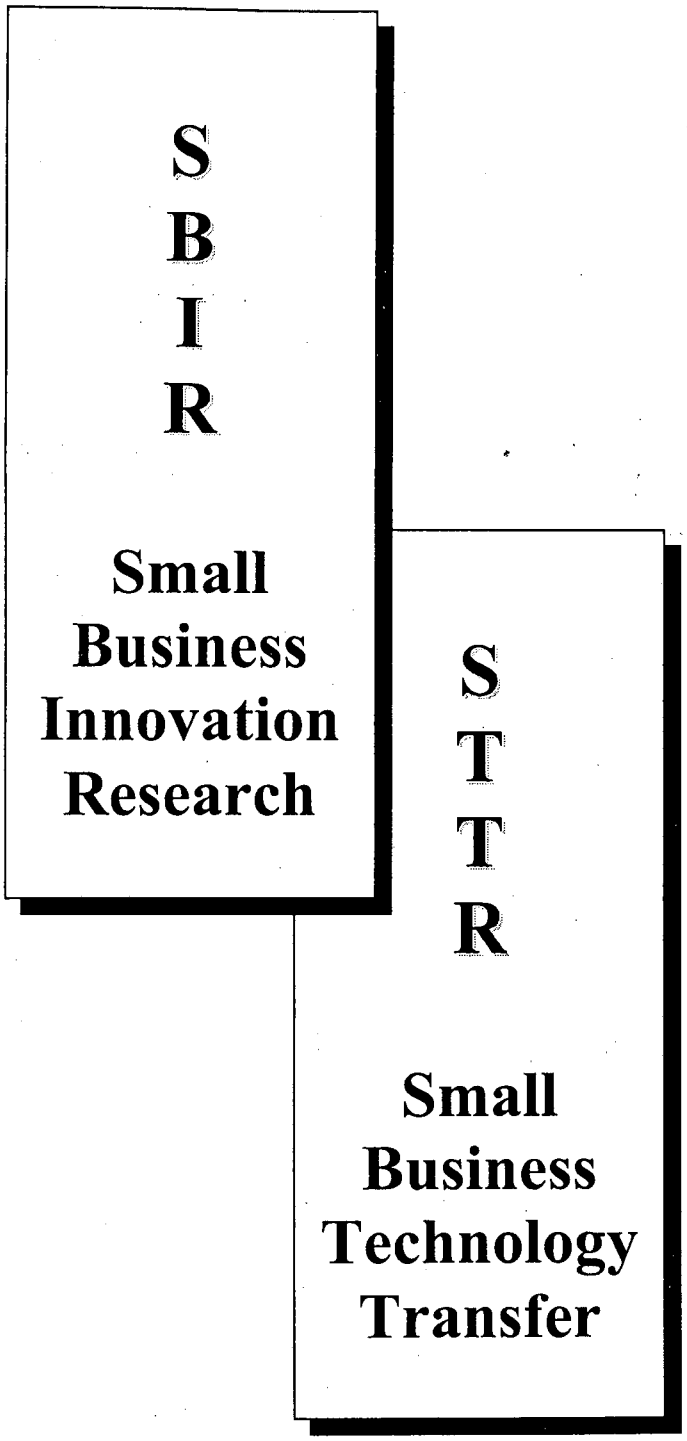
Small Business Technology Transfer

# Program Solicitations

*Closing Date: January 14, 2003*




**U.S. Department of Energy**
Office of Science, SC-32




# Technical

# Topic

# Descriptions

# PROGRAM AREA OVERVIEW – DEFENSE NUCLEAR NONPROLIFERATION

http://www.nn.doe.gov

The worldwide proliferation of Weapons of Mass Destruction (WMD) and their missile delivery systems is one of the most serious threats confronting the United States. The consequences for international security and stability are far reaching. The highly specialized scientific, technical, analytical, and operational capabilities of the Department of Energy, through the National Nuclear Security Administration (NNSA), Office of Defense Nuclear Nonproliferation (NA), and its national laboratories, is uniquely suited to provide leadership in national and international efforts to improve U.S. national security by reducing the threat posed by WMD. Within the Office of Defense Nuclear Nonproliferation, the Office of Nonproliferation Research and Engineering conducts applied research, development, testing, and evaluation – and leverages the work of others – to produce technologies that lead to prototype demonstrations and resultant detection systems, thereby strengthening the U.S. response to current and projected threats to national security and world peace posed by the proliferation of nuclear, chemical, and biological weapons, and the diversion of special nuclear material. Specific objectives include developing technologies for: (1) remote detection of the early stages of a proliferant's nuclear weapons program; (2) enhancing the U.S. nuclear explosion monitoring capability; (3) monitoring nuclear arms control agreements; (4) domestic detection and early warning of the chemical and biological agents, and minimizing their consequences; and (5) research on detection technologies for homeland security. Developed technologies are directly commercialized by the private sector.

Awardees will be required to comply with U.S. Laws on export control, including the "deemed export" rule. Information can be found at the following URL: http://www.bxa.doc.gov/

## 1. TECHNOLOGIES FOR NUCLEAR NONPROLIFERATION AND HOMELAND DEFENSE

The DOE Office of Defense Nuclear Nonproliferation (NA) sponsors the development of many types of sensors, data collection systems, and data analysis systems to detect the proliferation of weapons of mass destruction. The scope of this mission includes nuclear explosion monitoring, detection of the production of materials for nuclear weapons, and detection of illicit nuclear and radiological weapons in the United States. This topic focuses on the development of field deployable devices and data analysis systems. **Grant applications are sought only in the following subtopics:**

**a. Environmental Sensor Networks**—Grant applications are sought to develop environmental sensor networks for real-time monitoring of environmental (airborne) radiation levels, in order to provide data for pre-nuclear-event warning and post-nuclear-event assessment for use in event prediction and consequence management. The networks are to be deployed in urban environments and must supply local first responders and federal augmentation teams (including those from the Departments of Energy, Defense and Justice, and the Federal Emergency Management Agency) with detailed, accurate information regarding the fate and transport of radioactive environmental contaminants, so that they can mount a safe and effective response. A linkable, regional capability is envisioned, with fixed sensors deployed at key locations, and in sufficient numbers, to provide adequate coverage for early warning and input to post-event emergency response. The fixed sensors would be augmented by rapidly deployable sensors that could be readily added to the network. Grant applications may deal with the development of the complete sensor network (fixed and deployable), or focus on the fixed sensors alone. In either case, technologies are desired that support the rapid maturity, demonstration, commercialization, and deployment of the network. An overall system description and specification must be provided, including detector characteristics, communication protocols, infrastructure and maintenance requirements, conduct of operations, and estimated cost. The system can be designed for a particular urban area, or for a general urban area scalable to particular cities.

Data obtained via the network should: (1) not only be transmitted directly to the appropriate emergency

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

response center(s) but also shared with multiple agencies via the World Wide Web or other widely available sources; (2) be transmitted in, or converted to, a format that lends itself to display via commercially available Graphical Information System (GIS)/mapping software; (3) be of value under routine conditions in the absence of a nuclear or radiological threat, such as to provide a detailed map of radiation background in the urban environment; and (4) complement predictive models of radiation fate and transport, and possibly be assimilated into these models (as well as being ingested into pollutant fate and transport models), thereby increasing their fidelity.

**b. Low-Cost Consequence Management Personal Radiation Detector**—Grant applications are sought to develop instruments that combine a personal dosimeter with radiation survey capabilities. The instruments are intended for first responders (law enforcement, fire and rescue, hazmat, etc.); hence, they must be compact, light, rugged, have low power requirements and be easy to operate. The detector must be wearable and not interfere with the user's ability to meet the normal physical demands of the job. The instruments must integrate a wireless communication capability and a global positioning system (GPS). They must be sensitive to electromagnetic ionizing radiation (gamma rays) at levels approaching background (10-20 μR/hr), but capable of measuring and displaying radiation exposure rates (or dose rate equivalent) of 1000 – 100,000 times above background. Published standards for personal radiation detectors and dosimeters should be used to identify additional performance criteria. The devices must integrate the exposure (or dose) rate to provide personnel exposure (dose). Radiation exposure (dose) rates and integrated exposures (doses) can be displayed numerically, graphically, or as discrete "bins". The ability to detect thermal neutrons and display a count rate is also of value. Applicants must provide a conceptual design including detector characteristics, the physical dimensions and materials for the instrument, descriptions of the designs for electronics and communications, and a concept for operations.

**c. Field-Deployable Self-Cooled High Resolution Gamma Ray Spectrometers**—Grant applications are sought to develop rugged, self-contained, high resolution gamma ray spectrometers that are both portable and field-deployable. High resolution is defined as 0.5% at 662 keV (Full Width Half Max) or better. The detector must have an efficiency of at least 50% with respect to a 3" x 3" Sodium Iodide (NaI) scintillator. Spectrometers based on high purity germanium (HPGe) detectors will require integral self-cooling to achieve high resolution. Cooling systems based on cryogenic liquids must be self-contained and compact. Systems based on electromechanical coolers must provide sufficient isolation to eliminate acoustic interferences or reduce them to manageable levels. The instruments must have a cool-down time to operating temperature of 12 hours or less. Room temperature systems must provide high resolution spectra as defined above. Devices must be able to operate either with line- or battery-supplied electrical power. The design must provide for a spectrometer that is ruggedized for transportation and field operations. The development or adaptation of data analysis and system interface software running on a stand-alone laptop computer or personal data assistant must also be addressed. Applicants must provide a prototype design, including detector and multi channel analyzer (MCA) specifications, cooler design and operational characteristics (if applicable), power supply, system materials, and an estimated cost.

**d. Ground-Based Nuclear Explosion Monitoring**—The DOE/NNSA is responsible for the research and development necessary to provide the U. S. Government with capabilities for monitoring nuclear explosions, through its Nuclear Explosion Monitoring Research and Engineering (NEM R&E) program. The NEM R&E program provides research products to the Air Force Technical Applications Center, which collects and analyses data from a network of seismic, radionuclide, hydroacoustic, and infrasound data collection stations. Within the context of one or more of these technologies, grant applications are sought to develop algorithms, hardware, and software for improved event detection, location, and identification at thresholds and confidence levels that meet U.S. requirements in a cost-effective manner. Grant applications must demonstrate how the proposed approaches would complement and be coordinated with ongoing or completed work (see http://www.nemre.nn.doe.gov/coordination) while improving capability.

Grant applications are especially sought to develop low-noise seismometers for a network of seismic stations that is used to monitor for nuclear explosions. The seismometers must be deployable with tri-axial sensors at 100 meters depth in 7-inch boreholes. Sensor response must be flat to either velocity or acceleration over the bandwidth of operation. The seismometers must operate over the bandwidth 0.02 Hertz to 16 Hertz. This may require the development of two types of sensors: long period (0.02 Hertz to 4 Hertz) and short period (0.5 to 16 Hertz). Other requirements for the

seismometer include: (1) self-noise at least 6 dB below the USGS low-noise model for the full bandwidth of operation; (2) dynamic range (ratio of clip level to self-noise) at least 120 dB; (3) self-calibration within 5% for amplitude and within 5 degrees for phase over the full bandwidth of operation; (4) low power operation; and (5) high reliability, operation in harsh environments, and unattended functionality with very limited operator intervention. A representative set of the developed component(s) should be produced.

Grant applications are also sought for systems that will greatly improve the quality of the sensor data that is communicated to existing seismic stations, while reducing operation and maintenance costs. The sensor data must be collected continuously with very low noise and transmitted to a data center in near real time with high reliability (greater than 99%). Areas of interest include: (1) designs for robust, reliable wireless communication from each sensor site to the central location over rough terrain; (2) techniques for direct communication between the sensor site and the data center via satellite, for which satellite communication costs, as well as the size and power of field components, must be minimized; and (3) advanced power sources that can independently power the sensor site equipment maintenance-free for a prescribed period of time.

**References:**

**Subtopic a: Environmental Sensor Networks**


1. *Homeland Security Monitoring Network* U. S. DOE, Environmental Measurements Laboratory, www.eml.doe.gov/homeland

2. *NEWNET – Neighborhood Environmental Watch Network,* U.S.DOE Los Alamos National Laboratory, http://newnet.lanl.gov/concept.asp

3. *RODOS – Realtime Online Decision Support System for Nuclear Emergency Management* DSSNET, an international network on improvement, extension and integration of operational decision support systems for nuclear emergency management, www.rodos.fzk.de

4. Smith, J. Q., et al., "Probabilistic Data Assimilation within RODOS," *Radiation Protection Dosimetry*, 73(1/4): 57-59, 1997. (ISSN: 0144-8420)


**Subtopic b: Low-Cost Consequence Management Personal Radiation Detector**


5. *American National Standard Performance Criteria for Active Personnel Radiation Monitors*, New York: ANSI, 1995. (Document No. ANSI N 42.20)*

6. *Dosimeters and Alarm Ratemeters, Performance Requirements for Pocket-Sized Alarm*, New York: American National Standards Institute (ANSI), 1981 (R1992). (Document No. ANSI N 13.27)*


**Subtopic c: Field-Deployable Self-Cooled High Resolution Gamma Ray Spectrometers**


7. Knoll, Glenn F., *Radiation Detection and Measurement*, 3rd ed., New York: John Wiley & Sons, Inc., December 1999. (ISBN: 0471073385)


**Subtopic d: Ground-Based Nuclear Explosion Monitoring**


8. Erhard Wielandt, E., "Seismic Sensors and their Calibration," *Manual of Observatory Practice*, University of Stuttgart, Institute of Geophysics, 1997. (Full text available at: http://klops.geophys.uni-stuttgart.de/seismometry/man_html/)


* Available from ANSI. Telephone: 212-642-4980. Web Site: http://www.ansi.org/. Also available from Global Engineering Documents. Telephone: 800-854-7179. Web Site: http://global.ihs.com/.

## 2. SUPPORT TECHNOLOGIES FOR SENSORS USED IN NATIONAL SECURITY APPLICATIONS

The DOE Office of Defense Nuclear Nonproliferation (NA) sponsors the development of many types of sensors to help detect the proliferation of weapons of mass destruction. This topic is focused on the development of critical components that will enable or facilitate field deployment of these sensor systems. **Grant applications are sought only in the following subtopics:**

**a. Support Technologies for Active Imaging Systems**—Grant applications are sought for the development of a compact, portable seed laser with short (less than1 nanosecond) pulses, a narrow (less than 1

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

nanometer) spectral bandwidth, and an intermediate pulse repetition rate that is adjustable between 100 KiloHertz and 1 MegaHertz or wider. Pulse energy should be 10 nanoJoules or higher. Shorter pulses and higher pulse energy are preferred. Also important is a high pulse contrast ratio. Because further amplification and wavelength conversion is likely, a wavelength in the 1.0 to 1.5 micrometer range would be most useful. Lightweight, low power consumption, and small size (0.5 cubic feet or less for the laser, and a similar size for the associated power supplies/electronics) are also very important.

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

Finally, grant applications are sought for high-throughput optical components with throughputs of 5 $cm^2$-steradians or higher and with operation in the visible region of the electromagnetic spectrum. Components of interest include polarizers, narrow bandpass filters and fast (~100 nanosecond gate width) optical gates. Bandpass filters of interest must have a single bandpass of no more than 0.1 nanometers or multiple (3 or more) widely-separated bandpasses of 1 nanometer or less.

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

**b. Support Technology for Software Radio Systems**—NA is interested in Reconfigurable Computing (RCC) research with application to software radio. Software radio introduces digital techniques in the classical radio design, leaving the antenna and front-end circuitry as analog but converting the remainder of the system to host on-signal processing computers that are programmable to perform on-board processing for a variety of tasks. NA's applications drive the widest bandwidths (40-100 MegaHertz) known and therefore require super-computing I/O and processing capabilities. Recently, the RCC community was provided with advance information describing a revolutionary technology that integrates 3 Gigabit serial input/output (I/O) transceivers with a complete megagate FPGA (field programmable gate array), and multiple PowerPC 405 cores, all fabricated in the latest 0.13 micron CMOS (Complementary Metal-Oxide Semiconductor). This system-on-chip ASIC (application specific integrated circuit) promises to institute a new generation of highly integrated RCC systems, with many government and commercial applications. Grant applications are sought to develop hardware for an experimental signal processor board, based on this technology, that is capable of addressing all modern communications formats within a common hardware set, thereby reducing the number of hardware sets needed to perform modern radiofrequency and optical communications. The new integrated technology should be combined with the following capabilities: VME (VersaModule Eurocard), VXI (VME eXtension for Instrumentation), PCI (Peripheral Component Interconnect), or PMC (PCI Mezzanine Card) form factor; either Gigabit Ethernet or FibreChannel I/O; support for bus based, local ROM (Read-Only Memory), and test port programming; and cache SRAM (Static Random Access Memory) support, using multiple independent banks and at least 100 MegaHertz clock rates. Phase I should include initial systems studies and feasibility validations for the described board, system simulations and models of at least one test application for Software Radio, and a complete block diagram and camera ready layout for the proposed board, ready for construction if the Phase II project were awarded.

For further information or clarification of these requirements please contact Paul S. Graham (505-667-7024, grahamp@lanl.gov) or Scott Robinson (505-665-1954, shr@lanl.gov) at the Los Alamos National Laboratory.

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

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

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

(3) High-performance miniaturized gyros with one degree per hour bias or less. Airborne high-performance real-time synthetic aperture radar (SAR) systems use inertial measurement units (IMUs) that contain 3 gyros and 3 accelerometers -- the size of the IMU is typically dominated by the gyros. Tactical-grade IMUs have been used successfully (1 degrees/hour gyro bias) for fine-resolution SAR but are too large for proposed miniaturized SAR systems. Therefore, the program supports research for a small, lightweight gyro for these systems. Tactical performance levels are desired but it is anticipated that gyros with biases of 10-100 degrees/hour may be useful, albeit with a degradation of SAR performance.

(4) Miniature carrier-phase global positioning system (GPS) receivers. Global Positioning System (GPS) signals are transmitted from the GPS satellites to GPS receivers as pseudorandom-noise codes superimposed on carrier signals. The size, weight, and power required for these receivers have shrunk dramatically over the past few years. However, none of these small receivers can continuously track the GPS carrier phase, a signal that is critical for improved performance in a number of applications. Specifically, grant applications are sought for the development of miniature GPS receivers that can continuously track the GPS carrier phase.

(5) A solid-state wideband microwave power amplifier module to replace tube-based transmitters for short range applications. The system must have up to 100 Watts of peak power at a 35% duty factor and a 3 GigaHertz instantaneous bandwidth centered at Ku-band (16.7 GigaHertz). The module should be 15 cubic inches or less and must include microthermal technology (such as micro-heat-pipes) to control junction temperatures without sacrificing size.

(6) Solid-state wideband microwave power amplifier components which are MMICs (microwave integrated circuits). One example is the use of GaN HEMTS (Gallium-Nitride High Electron Mobility Transistors) that promise significant power output (greater than 5Watts/millimeter gate periphery) at traditional radar frequencies (X/Ku bands). The amplifier system must have up to 20 Watts of peak power per MMIC with greater than 40% efficiency, a 35% duty factor, and a 3 GigaHertz instantaneous bandwidth centered at Ku-band (16.7 GigaHertz).

(7) Miniaturized electro-mechanical systems (MEMS) microwave components. Radiofrequency (RF) MEMS technology offers the promise of ultra-low loss microwave switches, which could revolutionize transmit/receive (T/R) module design (low loss phase shifters and T/R switches). The insertion loss of this switch should be less than 0.25 dB over a frequency range of 15.2 GigaHertz to 18.2 GigaHertz. Additionally, MEMS technology could provide miniaturized, low-loss tunable filters that could be used to facilitate frequency agility and jamming resistance. The insertion loss of this filter should be less than 0.5 dB over a frequency range of 15.2 GigaHertz to 18.2 GigaHertz.

(8) Wideband phased-array antenna elements with a minimum of 3 GigaHertz bandwidth centered at the Ku-band (16.7 GigaHertz). Applicants may want to consider including Vivaldi elements.

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

**References:**

**Subtopic a. Support Technologies for Active Imaging Systems**


1. Baron, M. H., and Priedhorsky, W. C., "Crossed Delay Line Detector for Ground- and Space-Based Applications," *EUV, X-Ray and Gamma-Ray Instrumentation for Astronomy IV*, Proceedings of the SPIE (International Society for Optical Engineering), 2006:188-197, November 1993. (Available from SPIE at: http://spie.org/app/Publications/. Select Advanced Search and search papers by title words, authors and publication date.)




***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

2. Ho, C., et al. "Demonstration of Literal Three-Dimensional Imaging," *Applied Optics*, 38:1833-1840, 1999. (ISSN: 0003-6935)

3. Priedhorsky, W. C., et al., "Laser Ranging and Mapping with a Photon-Counting Detector," *Applied Optics*, 35:441-452, 1996. (ISSN: 0003-6935)

4. *Single Photon Detector and 3-D Imaging,* Los Alamos National Laboratory http://www.rulli.lanl.gov/

**Subtopic b. Support Technology for Software Radio Systems**

5. *Reconfigurable Computing Systems at LANL* Los Alamos National Laboratory, http://rcc.lanl.gov/

6. *XILINX: Programmable Logic Devices* http://www.xilinx.com/

**Subtopic c. Support Technologies for Synthetic Aperture Radar Systems**

7. *2001 IEEE MTT-S International Microwave Symposium Digest, Phoenix, AZ, May 20-25, 2001*, Piscataway, NJ: IEEE, 2001. (ISBN: 0-7803-6538-0) (IEEE Catalogue No. 01CH37157)

8. Kim, T. J., et al., "An Integrated Navigation System Using GPS Carrier Phase for Real-Time Airborne/Synthetic Aperture Radar (SAR)," Navigation, 48(1): 13-24, Spring 2001. (ISSN: 0028-8152)

9. *Synthetic Aperture Radar,* Sandia National Laboratories, http://www.sandia.gov/radar/sar.html

## 3. ENHANCED PROTEOMICS SIGNATURE ANALYSIS IN SUPPORT OF PATHOGEN DETECTION, BIOINFORMATICS, AND EPIDEMIOLOGICAL MODELING

The United States Department of Energy (DOE) is responsible for the development of systems to detect the presence of biological warfare agents intentionally released into the urban environment. Since the events of September 11th, successful aerosolization of solid-phase bioagent has been documented on several occasions (CDC article reference), resulting in an undesirable outcome for the exposed population. Early detection of a biological attack, whether by direct detection of airborne biological agents or rapid detection of those who have been exposed, is essential to minimize the impact of such attacks. Proteomic-based detection of bioagents is one of DOE's critical objectives. Establishing an in-depth understanding of the proteins inherent to these bioagents will facilitate the development of novel detection systems that will also complement genomic-based bioagent detection. **Grant applications are sought only in the following subtopics:**

**a. Protein Signatures for Detection**—Grant applications are sought for the development of novel biological agent protein signatures as well as the refinement of existing protein signatures for biological agent detection. Proposed approaches must be based on the isolation and biochemical characterization of target proteins from pathogen proteomes relevant to the Chemical and Biological National Security Program (CBNP) mission. Approaches of interest include, but are not limited to: (1) protein profiling using surface-enhanced and matrix-assisted laser desorption and ionization time-of-flight mass spectroscopy (SELDI/MALDI-TOF); (2) primary, secondary, and three-dimensional protein structure determination using a variety of methods including amino acid sequencing, two-dimensional gel electrophoresis, x-ray diffraction, and nuclear magnetic resonance spectroscopy; (3) development of structurally based high affinity ligands; (4) toxin and virulence factor structure/function determination; (5) classical antibody development; and (6) combinatorial receptor design or phage display.

**b. Protein Bioinformatics Algorithms**—Grant applications are sought for the development of computer algorithms that enhance current capabilities of analysis and prediction of protein structure and function. In particular, the structure and function of proteins of biological pathogens relevant to the CBNP mission are of interest. Proposed algorithms must organize and analyze primary protein structures for the purpose of predicting secondary and tertiary protein structure with a high confidence rate. For proteins with more than one component, prediction of the quaternary structure is desirable. Protein structure must be validated using x-ray crystallography, nuclear magnetic resonance, and/or electron microscopy. The protein structures generated by this grant may be used to create better pathogen detection tools and drugs to combat infectious disease. In addition, the information created by the algorithm will be added to existing proteomic biological databases, eventually aiding in the simulation of the complexity of living systems.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

Grant applications are also sought for the development of algorithms that will enhance current capabilities to: (1) identify and characterize proteins by amino acid composition; (2) translate nucleotide sequences to protein sequences and/or translate protein sequences back to nucleotide sequences; (3) search for structural homologs between multiple protein structures; (4) scan nucleotide sequences against protein profile databases; and (5) predict transmembrane regions for prokaryotic proteins.

**c. Protein Expression in Virulence**—Microorganisms that cause disease contain virulence factors that contribute to the virulence and survival of the microorganism. Various signals control the expression of these virulence factors. Grant applications are sought for the identification and characterization of proteins expressed from virulence genes in biological pathogens relevant to the CBNP mission. The actual role in pathogenicity of those genes and gene products that are prime virulence candidates should be ascertained. Proposed approaches must not only seek to uncover new virulence genes and expression products, but also define known virulence regulatory mechanisms in more detail. Approaches of interest include, but are not limited to: (1) virulence factor expression and regulation by signals including, oxygen, temperature, metal ion concentration, pH, and bacteria-host cell interaction; (2) protein purification and biochemical characterization of candidate virulence gene products; (3) site-directed mutagenesis of candidate genes and the subsequent purification and characterization of altered gene products; and (4) *in vivo* studies using animal models containing knock-out constructs of candidate virulence genes.

**References:**

**Subtopic a: Protein Signatures for Detection**


1. Mourez, M., et al., "Designing a Polyvalent Inhibitor of Anthrax Toxin," *Nature Biotechnology*, 19(10): 958-961, October 2001. (ISSN: 1087-0156)

2. Petricoin, E. F., et al., "Use of Proteomic Patterns in Serum to Identify Ovarian Cancer," *The Lancet*, 359:572-577, February 16, 2002. (ISSN: 0099-5355)


**Subtopic b: Protein Bioinformatics Algorithms**


3. Bayat, A., "Clinical Review: Bioinformatics," *British Medical Journal*, 324:1018-1022, April 27, 2002. (ISSN: 0959 8138) (Available from British Medical Journal at: http://bmj.com)


**Subtopic c: Protein Expression in Virulence**


4. Evdokimov, A. G., et al., "Overproduction, Purification, Crystallization and Preliminary X-Ray Diffraction Analysis of YopM, an Essential Virulence Factor Extruded by the Plague Bacterium Yersinia Pestis," *Acta Crystallographica Biological Crystallography*, 56(12): 1676-79, December 2000 (Available from Acta Crystallographica at: http://journals.iucr.org/. Search "Back Issues" of *biological Crystallography.)*

5. *Human Genome News*, U.S. DOE Human Genome Program, http://www.ornl.gov/hgmis/publicat/hgn/hgn.html


## PROGRAM AREA OVERVIEW - BIOLOGICAL AND ENVIRONMENTAL RESEARCH

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

The Biological and Environmental Research (BER) program sponsors research at national laboratories, universities, and private institutions to advance environmental and biomedical knowledge that promotes national security through improved energy production, development, and use; international scientific leadership that underpins our nation's technological advances; and environmental research that improves the quality of life for all Americans. In addition, BER delivers the knowledge needed to support the President's National Energy Plan, provides the science base in support of the Energy Policy Act of 1992, and works cooperatively with DOE's national security programs to develop tools to combat terrorism.

BER supports fundamental biomedical research and technology development needed to understand the fine structure and function of the human genome in order to provide the information needed to identify disease genes and develop broad therapeutic and diagnostic strategies. BER also sponsors advanced imaging and other medical technologies including

highly sensitive radiotracer detectors, radiopharmaceuticals, and innovative approaches to cell-targeted ablation therapy for cancer using *in vivo* radiation techniques. In support of the nation's biomedical, pharmaceutical, and environmental activities, BER projects often utilize unique facilities at the Department of Energy national laboratories to determine biological structure and how it relates to function at the molecular and cellular level.

BER also supports fundamental environmental remediation research necessary for the development of advanced tools for cleaning up the Nation's contaminated sites, particularly in support of DOE's Office of Environmental Management.

Lastly, BER supports fundamental climate change research to acquire the data and develop the understanding necessary to predict global and regional climate changes that may be induced by increasing atmospheric concentrations of greenhouse gases.

## 4. GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

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

**a. Genome Scale Reagent Sets**—There is an increasing availability of genomes as sequenced chromosomes with their constituent genes. These genes number in the 1000 thousands range for bacteria and in the 10-100 thousand range for higher organisms. Each gene may give rise to numerous distinct mRNAs and proteins, through processes of alternative RNA splicing and post-translational modifications. Micro-arraying methodologies are enabling highly parallelized interrogations of these hugh macromolecule collections. However, production and management systems are required to assure the availability of the numerous analytical reagents that are needed in small quantities. Grant applications are sought for: (1) systems that will produce thousands of affinity reagents (oligo-nucleotides, synthetic genes, antibodies and other affinity reagents) in pico-molar quantities; (2) miniaturized delivery systems for such reagent sets; (3) reagent sets for quantitation of RNA splicing; and (4) candidate RNAs for testing as regulatory agents.

**b. Protein Production and Analysis Methodologies**—The production of proteins for use in crystallographic analyses is an important task in structural biology. Several host-vector systems are available for the production of proteins encoded in a hyper-expressed source gene. However, for some source genes, the proteins fail to fold into physiologically effective 3D conformations; for example, entrapment in insoluble inclusion bodies is one cause of such failures. Problems also exist for proteins that are targeted to membranes. Also, affinity reagents that bind to proteins in their native conformations are needed for structure and function analyses. Grant applications are sought for the improved recovery and analysis of effective proteins. Areas of interest include: (1) production of solubilized proteins in active confirmations with or without post-translational modifications; (2) development of synthetic membranes or nano-structures enabling analyses of membrane proteins; and (3) development of affinity reagents for native proteins.

**c. Histological Analyses**—Capabilities to reveal the expression of individual genes in tissues have increased markedly. For example, the expression of individual genes as transcribed RNAs or their derivative proteins *in situ* is now routinely observed. However, support packages for automated image analysis, classification, and query have not kept pace. Few histological analysis

systems have commercial support. Grant applications are sought for systems, including hardware and software, that will automate expression reporting for histological analyses and provide effective querying capabilities for the datasets.

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

**References:**


1. "Bioscience: A Most Singular Study [single molecule methods]," *Berkeley Lab Highlights,* Berkeley Lab Research Review, Special Issue, 23(3), Fall 2000. (Available on the Web at: http://www.lbl.gov/Science-Articles/Research-Review/Highlights/2000/stories/bioscience/singular2.html

2. Parvin, B., et al., "BioSig: An Imaging Bioinformatic System for Studying Phenomics," *Computer*, 35(7): 65-71, July 2002. (ISSN: 0018-9162) (Available from IEEE Computer Society at: http://www.computer.org/computer/co2002/r7toc.htm)

3. "Post Sequencing Research Challenges," *Human Genome News,* U.S. DOE Human Genome Program http://www.ornl.gov/hgmis/publicat/hgn/v11n1/07post.html

4. *DOE Joint Genome Institute,* U.S. DOE Office of Biological and Environmental Research (OBER), http://www.jgi.doe.gov

5. *Genomes To Life: Biological Solutions to Energy Challenges* - U.S. DOE OBER/Office of Advanced Scientific Computing Research http://doegenomestolife.org/

6. *Human Genome Project Information* U.S. DOE Human Genome Program http://www.ornl.gov/hgmis

7. *Research Abstracts from the DOE Genome Contractor-Grantee Workshop IX, Oakland, CA, January 27-31, 2002,* U.S. DOE OBER http://www.ornl.gov/hgmis/publicat/02santa/index.html

8. *Research Topic,* U.S. DOE OBER http://www.sc.doe.gov/production/ober/restopic.html

9. *U.S. DOE Microbial Genome Program,* U.S. DOE OBER, http://www.ornl.gov/microbialgenomes/


## 5. MEDICAL SCIENCES

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

Principles of physics, chemistry, and engineering are being employed to advance fundamental concepts dealing with human health, to utilize the study of molecular interactions for a better understanding of organ function, and to develop innovative biologics, materials, processes, implants, devices, and informatics systems for the prevention, diagnosis, and treatment of disease and for improving human health. The DOE Advanced Medical Instrumentation program seeks to capitalize on the unique physical sciences and engineering capabilities at the DOE's national laboratories to develop new technologies that will have a significant impact on human health.

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

***Please note:*** ***(1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.***

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

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

**c. Advanced Imaging Technologies**—Grant applications are sought for new, sensitive, high resolution instrumentation for radionuclide imaging. The instrumentation should advance the application of radiotracer methodologies for imaging molecular biological functions including cell communication and gene expression *in vivo*. Areas of interest include the development of: (1) new detector materials and detector arrays for both positron emission and single photon emission computed tomography; (2) software for rapid image data processing and image reconstruction; and (3) methods of integrating *in vitro* and *in vivo* instrumentation technologies for real time molecular imaging of biological function and for new drug development and utilization.

**d. Cell-Targeted Ablation Therapy for Cancer with In-vivo Radiation Techniques**—Grant applications are sought for innovative approaches to cell-targeted ablation therapy for cancer with *in vivo* radiation techniques. The emphasis is on the therapeutic use of ionizing radiation such as may be achieved with radionuclide therapy or dual step techniques such as boron neutron capture therapy (BNCT). Specific goals include the development of novel ligands and delivery techniques to target and treat cancer at the cellular level. Proposed approaches should address such complex challenges as chemical ligand synthesis, tumor targeting by the proposed ligands, and anticipated biodistribution and dosimetry for the new ligands. With respect to BNCT, areas of interest include the design and development of either (1) new BNCT compounds or (2) novel and inexpensive mini-accelerators to create epithermal neutron beams suitable for BNCT applications.

**References:**


1. Barth, R. F., et al., "Boron Neutron Capture Therapy for Cancer: Realities and Prospects," *Cancer*, 70(12): 2995-3007, December 15, 1992. (ISSN: 0008-543X)

2. Klaisner, L. *Nuclear Science Symposium and Medical Imaging Conference: 1993 IEEE Conference Record*, IEEE Nuclear and Plasma Sciences Society, 2000. (ISBN: 0-7803-1488-3)

3. Reba, R. C., ed., "Introduction," *Journal of Nuclear Medicine*, Supplement, 36(6): 1S, June 1995. (ISSN: 0161-5505)

4. *U.S. DOE Medical Applications and Biophysical Division,* http://www.sc.doe.gov/production/oher/mab/mabrd.html

5. Wagner, H. N., et al., eds., *Principles of Nuclear Medicine*, 2nd ed., Philadelphia, PA: W. B. Saunders Co., 1995. (ISBN: 0-7216-9091-2)


## 6. ATMOSPHERIC MEASUREMENT TECHNOLOGY

World-wide energy production is modifying the chemical composition of the atmosphere and is linked with environmental degradation and human health problems. The radiative transfer properties of the atmosphere may be changing as well. Various

technological developments are needed for high accuracy and/or long term monitoring of these changes to support a strategy of sustainable and pollution-free energy development for the future.

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

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

Proposed systems must be capable of providing real-time measurements (i.e., the time for both sampling and response should be less than one minute) and be sufficiently sensitive to detect concentrations as low as 0.01-0.05 parts per billion. Rapid response instruments that are capable of flux measurements with response times of one second or less are of particular interest. Grant applications must include detailed descriptions of the instrumentation (including how it will connect to the atmosphere, for the purpose of sampling, without interference from intake losses or other confounding factors) and demonstrate how the proposed technique will result in improved aircraft and field measurement capabilities.

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

**c. High Accuracy Absolute Measurement of Infrared Radiation at the Surface**—Grant applications are sought to develop an absolute radiometric capability that can be used in the field as a standard for the measurement of atmospheric downwelling broadband infrared (all wavelengths longer than 4 micrometers) radiance at the surface. This instrument should scan over a hemisphere using a limited field of view (~ 5 degrees) aperture. New capabilities developed under this subtopic will be evaluated by comparison to the absolute sky scanner developed by the World Radiation Center (WRC) in Davos, Switzerland. The Davos absolute sky skanner measures infrared radiance within a narrow field of view using a pyroelectric sensor that is calibrated by pointing to an internal blackbody before



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

beginning each 32-point sky scan (8 azimuth by 4 elevation points). Analogous to the world (solar) radiometric reference, where absolute cavity radiometers of similar and mixed designs are used to calibrate direct solar beam measurements, the scanned hemispheric measurement capability developed in response to this subtopic, would be used to derive downwelling hemispheric irradiance for comparison to and calibration of field pyrgeometers.

**d. Instrumentation for Characterizing Organic Substances in Aerosol Particles**—Important insights into atmospheric pollution can be gained by understanding the characteristics and temporal changes of organic substances in ambient atmospheric aerosol particles with diameters less than about 2.5 micrometers. Grant applications are sought to develop instrumentation for real-time measurements that will: (1) provide accurate estimates of both mass and speciation of organic matter as a function of particle size; (2) detect the changing degree of oxygenation of the organics in aerosols, in order to evaluate the photochemical evolution of the organic aerosol; or (3) identify isotopic and molecular-level tracers of primary and secondary organic carbon, in order to help understand the origins of the fine particulate matter. The instrumentation and associated systems must account for such factors as polarity and water solubility, and must be capable of extended operation in an outdoor, field environment. Methods are needed that will provide accurate measurements of the organic aerosols with minimal artifacts (for example, semivolatile organics are known to absorb and desorb from filter media used to collect the organic aerosol samples) for both field and aircraft operations and for both organic carbon and black carbon. Examples of past approaches include determining 14C/12C isotopic ratios as a means of estimating fossil/biogenic hydrocarbon contributions to the aerosols, optical measurements of the "blackness" of the sample as a means of determining black carbon (soot) contributions, and thermal evolution techniques.

**References:**


1. Capasso, C., et al. "Quantum Cascade Lasers: Band-Structure Engineering Has Led to Fundamentally New Laser with Applications Ranging from Highly Sensitive Trace-Gas Analysis to Communications," *Physics Today*, 55:34-40, May 2002. (ISSN: 0031-9228)

2. Chou, M. D. and Peng, L., "A Parameterization of the Absorption in the 15 Micron $CO_2$ Spectral Region with Application to Climate Sensitivity Studies," *Journal of the Atmospheric Sciences*, 40:2183-2192, September 1983. (ISSN: 0022-4928)

3. Daum, P. H., et al., "Analysis of the Processing of Nashville Urban Emissions on July 3 and July 18, 1995," *Journal of Geophysical Research,* 105(7): 9155-9164, April 16, 2000. (ISSN: 0148-0227)

4. Eatough, D. J., et al., "A Multiple-System Multi-Channel Diffusion Denuder Sampler for the Determination of Fine-Particulate Organic Material in the Atmosphere," *Atmospheric Environment, Part A: General Topics*, 27A(8): 1213-1219, June 1993. (ISSN: 0004-6981)

5. Ellingson, R. G., et al., "The Intercomparison of Radiation Codes Used in Climate Models--Long Wave Results," *Journal of Geophysical Research*, 96:8929-8953, May 20, 1991. (ISSN: 0148-0227)

6. Fehsenfeld, F. C., et al., "Ground-Based Intercomparison of Nitric Acid Measurement Techniques," *Journal of Geophysical Research*, 103(3): 3343-3353, 1998. (ISSN: 0148-0227)

7. Gogou, A. I., et al., "Determination of Organic Molecular Markers in Marine Aerosols and Sediments: One Step Flash Chromatography Compound Class Fractionation and Capillary Gas Chromatographic Analysis," *Journal of Chromatography*, 799(1-2): 215-231, March 13, 1998. (ISSN: 0021-9673)

8. Grosjean, D., et al., "Evolved Gas Analysis of Secondary Organic Aerosols," *Aerosol Science and Technology*, 21(4): 306-324, 1994. (ISSN: 0278-6826)

9. Hansen, A. D. A., et al., "The Aethalometer–An Instrument for the Real-Time Measurement of Optical Absorption by Aerosol Particles," paper present at the *International Conference on Carbonaceous Particles in the Atmosphere, Linz, Austria, September 11, 1983*, Berkeley, CA: Lawrence Berkeley Laboratory, August 1983. (DOE Report No. LBL-16106) (NTIS Order No. DE84000400. Available from National Technology Information Service. See Solicitation General Information and Guidelines, section 7.1)

10. Miloshevich, L. M. and Heymsfield, A. H., "A Balloon-Borne Continuous Cloud Particle Replicator for Measuring Vertical Profiles of Cloud Microphysical Properties: Instrument Design, Performance, and Collection Efficiency Analysis," *Journal of Atmospheric and Oceanic Technology*, 14(4): 753-768, August 1997. (ISSN: 0739-0572)

11. Philipona, Rolf, "Sky-Scanning Radiometer for the Absolute Measurement of Atmospheric Long-Wave Radiation," *Applied Optics: Lasers, Photonics, and Environmental Optics*, 40(15): 2376-2383, May 2001. (ISSN: 1539-4522)

12. Schiff, H. I., et al., "A Tunable Diode Laser System for Aircraft Measurements of Trace Gases," *Journal of Geophysical Research C, Oceans and Atmospheres*, 95(7): 10147-10153, June 20, 1990. (ISSN: 0196-2256)

13. Spicer, C. W., et al., "A Laboratory in the Sky: New Frontiers in Measurements Aloft," *Journal of Environmental Science and Technology*, 28(9): 412A-420A, September, 1994. (ISSN: 0013-936X)

14. Williams, E. J., et al., "An Intercomparison of Five Ammonia Measurement Techniques," *Journal of Geophysical Research C, Oceans and Atmospheres*, 97(11): 11591-11611, 1992. (ISSN: 0196-2256)

15. Wulfmeyer, V., "Investigation of Turbulent Processes in the Lower Troposphere with Water Vapor DIAL and Radar-RASS," *Journal of the Atmospheric Sciences*, 56:1055-1076, April 1999. (ISSN: 0022-4928)

## 7. CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

Eighty-five percent of our nation's energy results from the burning of fossil fuels from vast reservoirs of coal, oil, and natural gas. These processes add carbon to the atmosphere, principally in the form of carbon dioxide ($CO_2$). It is important to understand the fate of this excess $CO_2$ in the global carbon cycle in order to assess the terrestrial ecosystem response, the sensitivity of climate, and the potential for sequestration in natural carbon sinks of lands and oceans. Therefore, improved measurement approaches are needed to quantify carbon changes in components of the global carbon cycle, particularly the terrestrial biosphere, in order to improve understanding and assess the potential for future carbon sequestration.

A DOE working paper on carbon sequestration science and technology describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems (see Reference 2). This document calls for substantially improved technology for measuring carbon transformation of the atmosphere and biosphere. The document also describes advanced sensor technology and measurement approaches that are needed for detecting changes of carbon quantities of terrestrial (including biotic, microbial, and soil components) and oceanic systems, and for evaluating relationships between these carbon cycle components and the atmosphere.

Grant applications submitted to this topic should demonstrate performance characteristics of proposed measurement systems, and show a capability for deployment at field scales ranging from experimental plot size (meters to hectares of land -- with comparable dimensions for marine systems) to nominal dimensions of ecosystems (hectares to square kilometers). Research to develop miniaturized sensors to determine atmospheric $CO_2$ concentration is also encouraged. In addition, Phase I projects must perform feasibility and/or field tests of proposed measurement systems to assure high degree of reliability and robustness. Combinations of remote and *in situ* approaches will be considered, although priority will be given to ideas/approaches for verifying biosphere carbon changes and for estimating carbon sequestration.

Lastly, applicants with an interest in collaboration should be aware of the DOE Consortium for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE) at Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). The co-directors are Gary Jacobs (ORNL/e-mail: jacobsgk @ornl.gov) and Blaine Metting (PNNL/e-mail: fb_metting@pnl.gov). Other possible collaborators include scientists from Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, the Rodale Institute in Pennsylvania, and the Joanneum Research Institute in Austria. **Grant applications are sought only in the following subtopics:**



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**a. Sensors and Techniques for Measuring Terrestrial Carbon Sinks and Sources**—Measurement technology is required to quantify carbon sequestration by natural vegetation and ecosystems (i.e., carbon sinks) as well as $CO_2$ emissions to the atmosphere from natural or industrial sources. Grant applications are sought to develop remote, ground-based sensors and unique measurement techniques (and associated system technology, if appropriate) to detect and quantify annual net carbon changes of terrestrial vegetation for large areas, or to measure and verify the magnitude of $CO_2$ emissions from various sources. For the measurement of $CO_2$ sinks, the sensor systems or new technology must be applicable for forests, grasslands, shrub lands, agricultural lands, and/or wetlands, and have the capability of producing spatially resolved aggregate estimates of terrestrial carbon changes to an accuracy of 10 to 25 $g/m^2/yr$ (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty. For measuring emissions, the apparatus must be located at a point remote from the actual site of $CO_2$ release and provide accuracy estimates for $CO_2$ concentrations of approximately 0.5 ppm or less. Grant applications are also sought to design and demonstrate a new $CO_2$ analyzer with the following characteristics: (1) ability to determine the mole fraction of $CO_2$ in dry ambient air to a relative precision of 1 part in 3000 or better in one minute or less; (2) low gas use (30 cc/min or less) to minimize problems due to water vapor and to minimize consumption of reference gases, if employed; (3) robust enough for unattended field deployment for periods of half a year or longer; (4) cost less than $5000 when manufactured in quantity; and (5) not sensitive to motion.

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

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

**b. Novel Measurements of Organic Substances and Carbon Isotopes in Terrestrial and Atmospheric Media**—Improved measurement technology is needed to better characterize processes involving carbon transformations of soil, vegetation, and associated ecosystem components and exchanges with the atmosphere. This includes both carbon content and isotopic measurements of organic matter in soils and other solid substrates, as well as the carbon content of biological tissues in various components (e.g., phytomass, detritus) of terrestrial ecosystems.

Grant applications are sought for measurements of carbon content in the atmosphere, vegetation, soil, and associated environmental media. For measurements involving the carbon content of biota and soil, grant applications must demonstrate that these measurements can be used to predict changes in carbon quantities and/or fluxes involving major components of ecosystems, with an accuracy on the order of 10 grams per square meter or less. Quantification of spatially resolved aggregate estimates of terrestrial carbon changes should have an accuracy of 10 to 25 $g/m^2/yr$ (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty.

For measurements of atmospheric $CO_2$, development of lightweight (approximately 100 gram) sensors capable of measuring fluctuations of $CO_2$ in air of the order of plus or minus 1 ppm in a background of 370 ppm is solicited. The devices must be suitable for launch on ballonsondes or similar such platforms, and therefore must be insensitive to large changes in ambient temperature and pressure. They must be able to operate on low power (e.g., 9v battery), and have a response time of less than 30 seconds.

Grant applications are also sought for unique, rapid, and cost-effective methods for measuring the natural carbon isotopic composition of plant, soil, and atmospheric materials. The idea is to use isotope technology to identify sources and sinks of carbon materials, and to use carbon isotopes to distinguish relative carbon exchanges between terrestrial or aquatic media and the atmosphere. New isotope approaches and technology should demonstrate a quantitative capability for both estimating

and distinguishing carbon flux among atmosphere, biosphere, and soil components of natural and manipulated carbon cycles.

Proposed new measurements of terrestrial biota and soil must be accomplished by *in situ* and/or non-invasive means and/or remote sensing of organic carbon forms across a range of temporal scales (from seconds to days) and spatial scales (from millimeters to kilometers), depending on the system properties being observed. Instruments must be portable and deployable in remote locations, and must not adversely impact the site of deployment. The term "remote sensing" means that the observation method is physically separated from the object of interest. Research that develops unique surface-based observations and uses them for calibration/interpretation of other remotely derived data is of interest; however, except for potential application of $CO_2$ sensor via ballonsonde, other methods of remote sensing data acquisition by airborne or satellite platforms will not be considered.

**References:**


1. Allen, L. H., Jr., et al., eds., "Advances in Carbon Dioxide Effects Research," *American Society of Agronomy, Special Publication No. 61*, Madison, WI: ASA, CSSA, and SSSA, 1997. (ISBN: 0-89118-133-4) (Available from ASA, CSSA, SSSA Headquarters Office. Telephone: 608-273-8090. (Web page: http://www.asa-cssa-sssa.org/cgi-bin/Web_store/web_store.cgi?page=special_publications_asa.html&cart_id=6208152_31794)

2. *Carbon Sequestration State of the Science: A Working Paper for Roadmapping Future Carbon Sequestration R&D*, Draft, Washington, DC: U.S. Department of Energy Offices of Science and Fossil Energy, 1999. (Available on the Web at http://www.fetc.doe.gov/publications/press/1999/seqrpt.pdf

3. Daniels, D. J., *Surface Penetrating Radar*, London: The Institution of Electrical Engineers, 1996. (ISBN: 0-85296-862-0)

4. Hall, D. O., et al., eds., *Photosynthesis and Production in a Changing Environment: A Field and Laboratory Manual*, New York: Chapman & Hall, 1993. (ISBN: 0412429004)

5. Hashimoto, Y., et al., eds., *Measurement Techniques in Plant Science*, San Diego: Academic Press, Inc., 1990. (ISBN: 0-12-330585-3)

6. McMichael, B. L. and Persson, H., eds., *Plant Roots and Their Environment: Proceedings of an ISRR Symposium, Uppsala, Sweden, August 21-26, 1988*, New York: Elsevier, 1991. (ISBN: 0-444-89104-8)

7. Nelson, D. W. and Sommers, L. E., "Total Carbon, Organic Carbon, and Organic Matter," *Methods of Soil Analysis, Part 3: Chemical Methods*, pp. 961-1010, Madison, WI: Soil Science Society of America, 1996. (ISBN: 0-89118-825-8)

8. Rozema, J., et al., eds., *$CO_2$ and Biosphere*, Hingham, MA: Kluwer Academic Publishers, 1993. (ISBN: 0792320441) (This publication is part of a monographic series, *Advances in Vegetation Science*, Vol. 14 - ISSN: 0168-8022) (Reprinted from *Vegetation*, 104/105, January 1993 - ISSN: 0042-3106. Now called *Plant Ecology* - ISSN: 1385-0237)

9. Swift, R., "Organic Matter Characterization," *Methods of Soil Analysis, Part 3: Chemical Methods*, pp. 1011-1070, Madison, WI: Soil Science Society of America, 1996. (ISBN: 0-89118-825-8)


## 8. BIOLOGICAL CARBON SEQUESTRATION RESEARCH AND TECHNOLOGY

The burning of fossil fuels adds carbon to the atmosphere, principally in the form of carbon dioxide, and the potential environmental impacts have made carbon management an international concern. There is increasing national and international interest in enhancing natural mechanisms to slow the rate of atmospheric $CO_2$ increase, or in developing new approaches to mitigate the current atmospheric rise in $CO_2$ levels. A DOE report on carbon sequestration science and technology (see reference 7) describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems, including a discussion of advanced biological processes and chemical approaches. This topic focuses on biological mechanisms that offer the potential to slow the rate of atmospheric $CO_2$ increase, convert carbon into relatively stable organic or inorganic forms, and utilize biosystems to achieve the simultaneous production of fuel or chemicals while sequestering carbon. Research is needed to identify and quantify mechanisms for $CO_2$ transformation at rates that will

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

lead to the long term fixation or sequestration of large quantities of carbon (i.e., where10,000 to 100,000 tonnes or more of carbon per year transformed or fixed is considered significant) when applied to either natural (e.g., unmanaged terrestrial ecosystems) or managed biosystems.

Plants are known to fix $CO_2$ into biomass, and various terrestrial and aquatic microbial populations also fix greenhouse gases ($CO_2$, $CH_4$ and CO), either incorporating them into biomass or transforming them to potentially useful organic compounds. Biochemical pathways have been identified in unicellular microorganisms that carry out the following transformations: (1) $CO_2$ to $CH_4$ (methanogens); (2) $CO_2$ to organic material, *i.e.*, biomass and/or other potentially useful byproducts (nonmethanogenic autotrophs); (3) CO to organic material (various, including carboxydotrophs, and methylotrophs); and (4) $CH_4$ to organic material (methanotrophs). These desired activities are characteristic of bacteria, archaeae, unicellular algae, and yeasts. The useful microorganisms may be either photosynthetic (as are algae and blue-green bacteria) or nonphotosynthetic (most microorganisms).

In some cases, microbial carbon fixation activity leads to the direct production of long-chain hydrocarbons (up to $C_{36}$). Both $CH_4$ and hydrocarbons are useful fuels, as is $H_2$, which is also produced by various microorganisms such as autotrophs. This $H_2$-producing activity may occur directly via carbon fixation, or indirectly by the reductive biotransformation of organic carbon-sequestration products by other microbes. Alternatively, some micro-organisms that are capable of fixing $CO_2$, $CH_4$, or CO, may instead, when coupled to other fermentative microbial cultures (e.g., bacteria or yeast) in a two-stage process, transform the gaseous substrates to useful alcohols (e.g., ethanol or 2,3-butanediol). Other two-stage processes can produce oxychemicals that are themselves valuable commodity chemicals (acetate, lactate, acetaldehyde, acetoin, etc.).

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

The facilities and expertise of the DOE Consortium for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE) can be made available to potential SBIR applicants to this topic. The CSITE is a consortium based at Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). The co-directors are Gary Jacobs (ORNL/e-mail: jacobsgk@ornl.gov) and Blaine Metting (PNNL/e-mail: fb_metting@pnl.gov). Scientists at Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, and the Joanneum Research Institute in Austria can also provide support to potential applicants. The DOE also supports carbon sequestration research at the National Energy Technology Laboratory (NETL). **Grant applications are sought only in the following subtopics:**

**a. Plant and Soil Sequestration of Carbon—** Terrestrial vascular plants effectively capture $CO_2$ from the atmosphere and produce organic compounds, which sustain productivity of the Earth's ecosystems. Some of the fixed carbon is sequestered in soils or sediments and in wood products of terrestrial ecosystems. Woody species, for example, sequester carbon as lignocellulose, which is a stored product for the lifetime of the tree. Also, above- and below-ground biomass carbon contributes to soil organic matter, which may store carbon for long periods of time. Grant applications are sought to identify and quantify the biological pathways and mechanisms leading to increased quantities of carbon sequestration by biotic and soil components of terrestrial ecosystems. Areas of particular interest include: (1) research on plant metabolic pathways or mechanisms that allow increased $CO_2$ fixation rates, achieved through conventional molecular or traditional genetic means, and leading to overall productivity increases; (2) novel technologies for managing vegetation (such as cost-effective nutrient management, forest regeneration, and ecosystem modification) to enhance carbon uptake and retention, thereby

significantly increasing $CO_2$ fixation and C storage; (3) techniques for increasing the fraction of recalcitrant organic compounds produced during natural microbial conversion of plant biomass in soils, resulting in increased long-term C-storage; and (4) measurement techniques that would allow for the validation of technologies developed to enhance net long-term C sequestration in man-made and natural environments.

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

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

**c. Production of Commodity Chemicals**—Grant applications are sought to identify and characterize new one- or two-stage biosystems capable of fixing carbon along with the production of nonfuel commodity chemicals – acids, alcohols, and/or aldehydes. ("Stage" refers to a discrete microbial culture containing either a single organism or a consortium – two-stage cultures are operated sequentially. "Biosystem" refers to a culture grown in a bioreactor.) Although a single biosystem would not be expected to perform all of these tasks, a single stage biosystem that produced large amounts of biosolids would still be of interest – provided that the biosolids could be used as petrochemical-sparing feedstocks for chemical production (either via traditional methods or as agricultural soil amendments via composting). For biosolids produced as chemical feedstocks, no special attributes are required. However, biosolids produced for agricultural purposes must be more resistant to subsequent biodegradation than typical cellulosic materials. Areas of interest include (1) the identification of new, naturally-occurring microorganisms with acceptable carbon-sequestering abilities; (2) the identification of novel configurations for growth of useful microorganisms at the expense of greenhouse gases, or (3) a combination of (1) and (2).

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

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

Proposed approaches based on these new biosystems must show significant potential for rapidly fixing large quantities of carbon. An acceptable carbon sequestration rate would be the consumption of at least 5 grams of carbon (expressed on an atom basis) per gram cell dry weight per hour, at an ambient temperature of at least 15 degrees C. This rate corresponds to a generation time of



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

no less than approximately 24 hours. In the case of chemical production, the overall process must demonstrate a net $CO_2$ consumption through the formation of biomass as a by-product. (It is understood that $CO_2$ production, through normal cell metabolism, is unavoidable, but significant net yield of fixed carbon should be the design objective and performance measure.) Phase I must demonstrate basic feasibility and efficacy of the proposed carbon sequestration mechanisms on a bench scale. Larger, pilot-scale demonstrations with emphasis on yield performance would be tested in Phase II.

**References:**


1. Belaich, J. P., ed., *Microbiology and Biochemistry of Strict Anaerobes Involved in Interspecies Hydrogen Transfer*, New York: Plenum Press, 1990. (ISBN: 0-306-43517-9) (FEMS Symposium)

2. *Greenhouse Gases, Global Climate Change and Energ,* U.S. DOE National Energy Information Center, 2002. http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html

3. Jefferson, J., *Looking to the Light*, 2000. (Available on the Web at: http://www.ornl.gov/ornl94/looking.html)

4. Lal, R., ed., *Soil Processes and the Carbon Cycle*, Boca Raton: CRC Press, 1998. (ISBN: 0-8493-7441-3)

5. Ratledge, C., ed., *Biochemistry of Microbial Degradation*, Netherlands: Kluwer Academic Publishers, 1994. (ISBN: 0-7923-2273-8)

6. References from Technical Sessions 3C, 4C, 5C, *First National Conference on Carbon Sequestration, Washington, DC, May 14-17, 2001.* (Available on the Web at: http://www.netl.doe.gov) (Select "Publications" from menu on left. Scroll down and select "Conference Proceedings." A list of conferences in chronological order will appear, with the most recent loaded first. Scroll down and select conference title.)

7. Reichle, D., et al., *Carbon Sequestration Research and Development*, Washington, DC: U.S. Department of Energy Offices of Science and Fossil Energy, 1999. (Full text available at http://www.ornl.gov/carbon_sequestration/)

8. Rosenberg, N. J., et al., eds., "Carbon Sequestration in Soils: Science, Monitoring and Beyond," *Proceedings of the St. Michaels Workshop, St. Michaels, MD, December 1998*, Columbus, OH: Battelle Press, 1999. (ISBN: 1-57477-084-5) (Available from Battelle Press. Telephone: 800-451-3543. Web site: http://www.battelle.org/bookstore. Search by author.) (Summary and conclusions available on the Web at: http://www.cast-science.org/9812carb.htm)

9. Rozema, J., et al., eds., *$CO_2$ and the Biosphere*, Boston, MA: Kluwer Academic Publishers, 1993. (ISBN: 0792320441) (Also in *Advances in Vegetation Science*, Vol. 14. ISSN: 0168-8022)

10. Various articles from *Natural Sinks of $CO_2$: Proceedings of the Palmas Del Mar Workshop, Palmas Del Mar, Puerto Rico, February 24-27, 1992*, Water, Air and Soil Pollution, 64(1-2), 1992. (ISSN: 0049-6979)


## 9. MEASUREMENT/MONITORING TECHNOLOGIES FOR THE SUBSURFACE ENVIRONMENT

The characterization and monitoring of soils, subsurface sediments, and groundwater are important elements of Department of Energy (DOE) research efforts. Objectives include determining the fate and transport of wastes generated from past weapons production activities and from current energy production activities, evaluating the risks of energy-related contaminants to human health and ecosystems, and assessing and controlling processes to remediate contaminants. Grant applications submitted to this topic must detail why and how proposed *in situ* field technologies will substantially improve the state-of-the-art and must include bench tests to demonstrate the technology. Projected dates for likely operational field deployment must be clearly stated. New or advanced field technologies that operate under field conditions with mixed/multiple contaminants and that can be deployed in 2-3 years will receive selection priority. Claims of commercial potential for proposed technologies must be supported by information such as endorsements from relevant industrial sectors, market analysis, or identification of commercial spin-offs. Grant applications that propose incremental improvements or enhancements to existing technologies are not of interest and will be declined, as will enhancements to predictive models.

For some of the following subtopics, collaboration with government laboratories or universities may speed the development of the measurement or monitoring technology. For example, the Environmental Molecular Sciences Laboratory, a DOE scientific user facility located in Richland, WA, can provide analytical instrumentation and capabilities with direct application to sensor development and testing. Potential applicants are invited to consult web sites for their Chemistry and Engineering (http://www.emsl.pnl.gov:2080/homes/ice/ – for subtopics a, b, and c) and Environmental Dynamics and Simulation (http://www.emsl.pnl.gov:2080/homes/eds/ – for subtopic b) groups. Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements. **Grant applications are sought only in the following subtopics:**

**a. Real-Time, *In Situ* Measurements in Soils, Subsurface Sediments, or Groundwater**—There is a need for sensitive, accurate, and real-time monitoring of geochemical and hydrogeologic processes and their interactions with microorganisms in contaminated soils, sediments, or groundwater environments (hereafter referred to as the subsurface). The use of highly sensitive monitoring devices in the subsurface (*in situ*) would allow for low-cost field deployment in remote locations and an enhanced ability to monitor processes at finer levels of resolution. For this subtopic, the following radionuclides and metals are of interest: americium, cesium, chromium, cobalt, mercury, plutonium, strontium, technetium, and uranium. In addition, chelators such as ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acid (NTA), and catechol derivatives (e.g., disodium-1.2-dihydroxybenzene-3,5,-disulfonate) will be considered. Grant applications that address other contaminants will be declined.

Grant applications are sought to develops sensors and systems to: (1) detect hydrogeologic and biogeochemical processes that control the transport, dispersion, or transformation of contaminants (particularly metals and radionuclides) in the subsurface; (2) determine characteristics such as concentration, movement, or speciation of contaminants in the subsurface; and/or (3) measure mass-transfer processes and rates within and among individual pores in the subsurface. Grant applications must provide convincing documentation (experimental data, calculations, etc.) that the sensing method is both highly sensitive (i.e., low detection limit) and highly selective to the target analyte (i.e., immune to anticipated physical/chemical/biological interferences). Approaches that leave significant doubt regarding sensor functionality in realistic multi-component samples will be excluded from consideration.

Grant applications are also sought for integrated sensing and controller/signal processing systems for autonomous or unattended applications of the above measurement needs. Innovative integration of components (such as micro-machined pumps, valves, and micro-sensors) into a complete sensor package with field applications in the subsurface will be considered responsive to this subtopic.

Approaches of interest could include fiber optic, solid-state, chemical, silicon micro-machined sensors, or biosensors (devices employing biological molecules or systems in the sensing elements) that can be used in the field. Biosensing systems may incorporate, but are not limited to, whole cell biosensors (i.e., chemoluminescent or bioluminescent systems), enzyme or immunology-linked detection systems (e.g., enzyme-linked immunosensors incorporating colorimetric or fluorescent portable detectors), lipid characterization systems, or DNA/RNA probe technology with amplification and hybridization. As substantial progress has been made in fiber optics and chemical sensing technology in the last decade, grant applications that propose minor adaptations of readily available materials/hardware, and/or cannot demonstrate substantial improvements over the current state-of-the-art, are not of interest and will be declined.

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

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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

Potential monitoring technologies could include any of the following techniques: (1) spectral reflectance and thermal infrared measurement techniques, (2) laser-induced fluorescence spectroscopy and laser-induced fluorescence imaging, (3) laser-induced breakdown spectroscopy, (4) x-ray fluorescence, (5) ground-penetrating radar measurement, (6) chlorophyll fluorescence measurement, (7) ELISA-based, respirometric, or other biochemical measurement of metabolite production, and (8) molecular monitoring of soil and rhizosphere microbiology. Both remote monitoring and *in situ* monitoring approaches are of interest. Proposed technologies should significantly improve the speed, efficiency, and cost of current monitoring methods. While initial proof of principle experiments may focus on one single contaminant, the technology ultimately must be able to operate under mixed contaminant conditions such as those commonly found at DOE sites.

In addition to the potential sources for collaboration identified in the Introduction to this topic, scientists at the Savannah River Ecology Laboratory, located at the Savannah River Site in Aiken, SC, are involved in several on-going phytoremediation research projects (see references).

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

**d. Debris Characterization Technology**—As a result of the deterioration of storage drums, radionuclides have been released to surface and subsurface soils surrounding storage areas at sites within the Department of Energy complex. The soils of interest are non-homogeneous, consisting of soil, pebbles, cobbles, and small rocks. Grant applications are sought for a soil/debris characterization technology or combination of technologies for the *in situ*, real-time determination of radioactive contaminants, in order to reduce the volume of material to be excavated. For this subtopic, contaminants of interest to DOE include the following metals and radionuclides: americium, cesium, chromium, cobalt, plutonium, strontium, technetium, and uranium. To make informed, site-specific remediation decisions, the technology must be capable of providing real-time, *in situ* measurements of site-specific radioactive contaminants within buried debris prior to the removal or disturbance of the debris, which may be buried up to 20 feet deep. Expected detection limits for proposed approaches must be identified in the grant application.

**References:**


1. A National Roadmap for Vadose Zone Science and Technology, INEEL, National Vadose Zone Project, August 2001, http://www.inel.gov/vadosezone/

2. Dandridge, A. and Cogdell, G. B., "Fiber Optic Sensors - Performance, Reliability, Smallness," *Sea Technology*, 35(5): 31, May 1994. (ISSN: 0093-3651)

3. Egorov, O. B., et al., "Radionuclide Sensors Based on Chemically Selective Scintillating Microspheres: Renewable Column Sensor for Analysis of 99Tc in Water," *Analytical Chemistry*, 71(23): 5420-5429, December 1, 1999. (ISSN: 0003-2700)

4. Idaho National Engineering and Environmental Laboratory (INEEL) Science and Technology Needs, Environmental Management Program, 2001, http://www.inel.gov/st-needs/

5. *Natural and Accelerated Bioremediation Research Program Plan*, Washington, DC: U.S. Department of Energy, Office of Biological and Environmental Research, September 1995. (Report No. DOE/ER - 0659T) (NTIS Order No. DE96000157) (Full text available at: http://www.osti.gov/bridge)

6. Oak Ridge Operations Technology Needs [Database], U.S. DOE, Office of Environmental Management, 2001, http://www.em.doe.gov/techneed/

7. Phytoremediation Research, University of Georgia, Savannah River Ecology Laboratory http://www.uga.edu/srel/Fact_Sheets/phytoremediation.htm (Primary point of contact is currently Dr. Lee Newman. http://www.uga.edu/srel/faculty.htm).

8. Publications by Scientists within and External Users of the William R. Wiley Environmental Molecular Sciences Laboratory, 2002. http://www.emsl.pnl.gov:2080/docs/

9. Raskin, I., et al., *Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment*, New York: John Wiley & Sons, November 1999. (ISBN: 0471192546)

10. *Research Needs in Subsurface Science: U.S. Department of Energy's Environmental Management Science Program*, Washington, DC: National Academy Press, 2000. (ISBN: 0309066468) (Full text available at: http://www.nap.edu)

11. Riley, R. G., et al., *Chemical Contaminants on DOE Lands and Selection of Contaminant Mixtures for Subsurface Science Research*, Washington, DC: U.S. Department of Energy, April 1992. (Report No. DOE/ER- 0547T) (NTIS Order No. DE92014826) (Available from NTIS. Telephone: 1-800-553-6847. Web site: http://www.ntis.gov/support/orderingpage.htm)

12. Rivera H., et al., "A Microsensor to Measure Nanomolar Concentrations of Nitric Oxide," *Sensors*, 11(2): 72-73, February 1994. (ISSN 0746-9462)

13. Rocky Flats Technologies, Site Technology Coordination Group (2001) http://www.aimsi.com/rockyflats/stcg.htm

14. Tanks Focus Area, U.S. Department of Energy, 2001, http://www.pnl.gov/tfa

15. Technology Needs, Technology Division Site Technology Coordination Group, U.S. DOE Nevada Test Site, 2001 http://www.nv.doe.gov/programs/envmgmt/blackmtn/TDSTCGTechnologyNeeds.htm

16. Uranium Mill Tailings Remedial Action Ground Water Project, U.S. DOE, Grand Junction Office, http://www.doegjpo.com (In left-hand column, select "Projects and Programs," and then select project title.)

## PROGRAM AREA OVERVIEW - ENVIRONMENTAL MANAGEMENT

http://www.em.doe.gov

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

EM responsibilities include the remediation of radioactive and toxic wastes to their original background levels and the deactivation and decommissioning (D&D) of thousands of contaminated facilities. With regard to site remediation, DOE is responsible to locate and remediate plumes to prevent contamination of groundwater as well as the potential off-site

migration of the contaminated plume. New or improved technologies are sought to address issues related to materials for reactive barriers and for *in situ* monitoring systems to facilitate the use of reactive barriers. DOE is also responsible for reducing the volume of contaminated concrete and associated waste streams; therefore, new or improved technologies are needed to separate contaminates from concrete. DOE also sponsors research to reduce risks to workers from potential exposures associated with decontamination and decommissioning activities, therefore, new or improved technologies are sought for remote cutting or sizing technologies and for multi-purpose remote platforms.

The following two topics solicit grant applications for reactive barriers and monitoring systems for groundwater remediation and decontamination and decommissioning of facilities. Background information on the research needs associated with these topics can be found on the World Wide Web (http://www.em.doe.gov), by clicking on a State and under the Office of Science and Technology (http://apps.em.doe.gov/ost).

## 10. REACTIVE BARRIERS AND MONITORING SYSTEMS FOR SUBSURFACE REMEDIATION

Several DOE sites have plumes in the subsurface that are contaminated with metals, organics, and/or radionuclides. The plumes identified at DOE sites include a trichloroethylene-technetium plume at Paducah, a carbon tetrachloride plume at Hanford, a mercury plume at Oak Ridge, a polychlorinated biphenyl (PCB) plume at Oak Ridge, a uranium plume at Fernald, and a chromium plume at Lawrence Livermore. Details on these and other plumes can be found on the web at www.em.doe.gov. The current approach to remediating these plumes, once they are located, involves pump-and-treat operations, a process that manages, but may not eliminate, the risks associated with the plumes. A further concern is that the life-cycle costs for pump-and-treat operations may be significant and may impede final site closure. Another approach, which could be used along with pump-and-treat operations, involves the construction of barriers that react with the contaminant to prevent plume spread. The reactions are intended to convert the plume into a non-mobile form or to convert the contaminants into non-toxic materials. Both strategies may be required in order to eliminate both the risks associated with the contaminants as well as the potential for off-site contamination. In addition, reactive barriers may offer better life-cycle costs, better protection for the environment, and the elimination of some of the risks associated with contaminated plumes. However, before any approach can be attempted, the nature of the contamination must be characterized, often in difficult-to-access locations. Additional information on these needs can be found at the following websites: http://apps.em.doe.gov/ost/progstcg.html and http://www.cmst.org. **Grant applications are sought only in the following subtopics:**

**a. Materials for Reactive Barriers**—Reactive barriers usually consist of deep beds of reactive material (e. g., zero-valent iron, ion-exchange materials) placed in the path of the plume. A barrier could also be formed by incorporating reactive compounds in the soil in the path of the plume, including the soil surrounding the source of contamination. Because long-term plume control is desired, the barrier must contain sufficient material for treating all the contaminant in the plume or else the barrier material must be economically replaceable. Grant applications are sought to develop new barrier materials with either reactive or absorptive capabilities. Contaminants of interest include halogenated hydrocarbons such as trichloroethylene, carbon tetrachloride, and PCBs; inorganic contaminants such as lead, chromium, mercury, and other RCRA metals; and radioactive isotopes such as those of uranium, technetium, strontium, and cesium. Grant applications should clearly identify the contaminants to be addressed and the soil and subsurface conditions for the reactive barrier. Of particular interest are barrier materials capable of removing or stabilizing more than one contaminant. Barrier materials (1) must be capable of effective operation for long periods of time; (2) must be sufficiently selective so as not to be quickly consumed (if reactive materials) or loaded (if absorptive) by non-contaminant plume materials (target contaminants usually represent only a tiny fraction of plume material, and bulk ions, such as calcium and magnesium, which are almost always present in groundwater, must not load any reactive material or displace absorbed contaminant); and (3) must not degrade in use by, for example, biodegradation of organic barrier materials or poisoning of reactive materials. Finally, it is desirable that any spent barrier be easily disposed of in place or elsewhere. This requires that the spent barrier material be sufficiently stable to last indefinitely, be able to convert the pollutant into a stable form (as by mineralization), or be able to be regenerated.

**b. *In Situ* Monitoring Systems to Facilitate the Use of Reactive Barriers**—Monitoring systems are needed to determine the performance and integrity of reactive barriers. The development and deployment of such systems involves numerous challenges. Technical challenges include determining appropriate indicator parameters for the plume of interest, ensuring the longevity and continued integrity of the monitoring system itself, identifying appropriate ways of communicating monitoring data and other information to and from the system, and determining reliable maintenance strategies and schedules for the systems. Additional challenges involve replacing conventional monitoring practices, based on laboratory analysis of manually obtained samples, with strategies based on such remote monitoring systems, and achieving the acceptance of new systems and strategies by regulators and stakeholders. Grant applications are sought to develop i*n situ* remote monitoring systems for reactive barriers. Proposed systems should include: (1) autonomous reporting via secure wireless communications with a central information processing facility; (2) low power requirements, preferably using on-site solar panels; (3) no need, or at most minimal need, to recharge reagents; (4) zero, or at most minimal, production of secondary wastes; and (5) a capacity for self-testing and autocalibration. Contaminants of interest include any of the halogenated organic constituents, inorganics such as RCRA metals, and radionuclides. Grant applications should clearly identify the contaminants to be addressed and associated detection limits for the monitoring systems. Systems that are capable of detecting and quantifying multiple contaminants within a class, either without modification or with minor adjustments that can be made during system deployment, would be particularly useful. Communications support for such monitoring systems are available and, therefore, are not sought in this solicitation.

**c. Characterization Technologies for Difficult Subsurface Settings**—Soil and groundwater at many DOE sites have been contaminated with organic solvents, heavy metals, and radionuclides as a result of past operational and disposal practices. Often, this contamination occurs in subsurface settings that are difficult to efficiently and cost-effectively access for the purpose of characterizing the location and quantity of contamination. Specific examples of these subsurface settings include contamination that is: beneath buildings and other manmade structures such as underground tanks and buried pipelines; at depths that reach 45 meters or more; in difficult-to penetrate sediments such as beds of gravel or layers of caliche; and in highly heterogeneous geologic settings such as sediment facies containing complex interbeds and other structures for which fluid flow predictions are difficult. Grant applications are sought to reduce the cost or expand the capabilities characterizing and monitoring contaminants in difficult-to-access subsurface settings. Proposed approaches should include: (1) capability of providing real-time data, (2) detection limits down to required remediation levels, (3) capability of downloading data into computer systems for analysis and retrieval; and (4) ruggedness.

**References:**


1. *CLU-IN: Hazardous Waste Clean-Up Information,* Environmental Protection Agency, Technology Innovation Office, http://www.clu-in.org

2. *DOE Hanford Site,* http://www.hanford.gov/

3. *Environmental Technology,* U.S. DOE Oak Ridge Operations Environmental Management Program http://www.oakridge.doe.gov/em/td/default.htm)

4. *Federal Remediation Technologies Roundtable* http://www.frtr.gov

5. *Office of Science and Technology* (EM-50) U.S. DOE Office of Environmental Management, http://apps.em.doe.gov/ost/

6. *Savannah River Site* http://www.srs.gov/general/srs-home.html

7. *U.S. DOE Environmental Management Science Program,* http://emsp.em.doe.gov

8. *U.S. DOE Idaho Operations Office* http://www.id.doe.gov/doeid/index.html

9. *U.S. DOE Office of Environmental Management* http://www.em.doe.gov/


## 11. DECONTAMINATION AND DECOMMISSIONING OF FACILITIES

The DOE is responsible for the deactivation and decommissioning of numerous buildings and facilities that have handled toxic and radioactive materials since the 1940s. These facilities were used for chemical

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

separations, component and weapons fabrication, fuel/target fabrication, reactor operations, enrichment operations, and mining, milling, and refining. Deactivation refers to ceasing facility operations and placing the facility in a safe and stable condition to prevent unacceptable exposure of people or the environment to radioactive and other hazardous materials until the facility can be decommissioned. Decommissioning is the process of decontaminating or removing contaminated material and equipment to achieve the end state for the facility. Desired end states include complete removal and remediation of the facility, facility entombment, and release of the facility for either unrestricted or restricted use.

This topic focuses on three issues of concern to D&D operations: removing contaminants from concrete, using robotic technologies to reduce exposure to workers, and controlling airborne radiological contamination. Among contaminated materials, concrete is pervasive within these buildings and facilities, and particular attention must be paid to recycling the concrete and disposing of concrete debris. Improved robotic technologies would allow for remote operation, lower the risks to health and safety, and reduce life-cycle costs. Better control of airborne contaminants would further reduce health and safety risks to D&D workers and the environment during dismantlement or disassembly operations. **Grant applications are sought only in the following subtopics:**

**a. Separation Technologies for the Removal of Contaminants from Concrete**—The concrete in buildings and structures of DOE facilities is found in floors, walls, concrete covered beams and posts, etc. The concrete might be found cast in place or in concrete blocks, and its surfaces may contain paint or other coatings. Since concrete is a porous material, contamination could have penetrated a short distance below the surface; if the concrete were cracked, the penetration might be much greater. Grant applications are sought for new or improved methods for removing solvents, toxic metals, and/or radionuclides from concrete, including contaminants that may have penetrated short distances from the surface. Approaches of interest include electrokinetic methods, supercritical fluid extractions, and advanced leaching technologies. One or more of the following forms of contaminated concrete should be addressed: (1) concrete in floors, walls, and other structures in existing buildings; (2) scabble particles (residue left after physical methods remove the outer inch or so of the concrete surface, where most contamination is concentrated); (3) concrete rubble remaining after building demolition. Phase I should include tests on concrete with simulated contamination from stable isotopes of cesium and strontium, solvent, or toxic metals. Grant applications should explain how the contaminated concrete will be prepared and indicate what outcome (or range of outcomes) will be used to determine whether the proposed concept is working.

**b. Robotic Technologies for Automated Deactivation and Decommissioning**—D&D activities require workers to routinely enter areas contaminated with radioactive and other hazardous materials and work with powerful heavy equipment that is capable of breaching protective clothing. To reduce the potential risk to workers, there is a need for new or improved robotics and intelligent machines to perform these D&D functions remotely. Such improvements would be expected to reduce life-cycle costs and to lower health and safety risks to workers. Grant applications are sought to develop (1) a more efficient and universal remote cutting device and/or (2) a multi-purpose remote platform. Regarding (1) above, most cutting devices are material-specific, or function only on a limited number of materials. A universal cutter would function on a multitude of materials, shapes, and sizes and be adaptable for use on multiple robotic arms. The remote cutter must be capable of remote maintenance and produce a minimum amount of residual waste from the cutting process. Regarding (2) above, the multi-purpose remote platform must be equipped with an interchangeable apparatus capable of performing a variety of tasks including size reduction, radiation characterization, decontamination, and materials handling. The platform must be capable of operation in compact and congested areas, and tetherless operation is preferred.

**c. Control of Airborne Radiological Contamination**—Many facilities throughout the DOE complex are radiologically contaminated. This contamination has the potential to become airborne during dismantlement or disassembly operations as part of deactivation and decommissioning (D&D) activities. Radiological contamination poses safety and health risks to D&D workers, peripheral workers, and to the environment. Grant applications are sought to develop: (1) techniques to permanently affix the contamination without risking worker health or the environment; (2) techniques to completely capture removable contaminants so that there is no possibility of airborne radionuclide particles; (3) low-cost systems or materials to control loose surface contamination in the form of

low-level alpha emitters, which are difficult to detect but pose risks to worker health and safety; (4) a fixative to contain dispersible alpha contamination – the fixative must be easily applied to a variety of surfaces, last at least 20 years, and be easy to remove during the eventual decontamination of the facility; and (5) a method to capture airborne alpha contamination from a work area, such as a materials processing facility. Proposed approaches must not pose any additional hazard to workers, and must be at least as efficient as a glove bag. Any fixatives developed must meet Waste Acceptance Criteria (WAC) for the Waste Isolation Pilot Plant (WIPP).

**References:**


1. *Accelerating Cleanup: Paths to Closure*, U.S. DOE Office of Environmental Management (EM), June 1998. (Report No. DOE/EM-0362) (Available at: http://www.em.doe.gov/closure/)

2. *Characterization, Monitoring, and Sensor Technology Crosscutting Program,* U.S. DOE, EM Office of Science and Technology, http://www.cmst.org

3. *Deactivation and Decommissioning Focus Area* U.S. DOE National Energy Technology Laboratory, http://www.netl.doe.gov/dd)

4. *Deactivation and Decommissioning Information System* (DDIS)
   - OH-MB-215: Control of Loose Surface Contamination
   - RL-DD04: TRU Waste Fixatives for PFP
   - RL-DD062: A Method to Capture Airborne Alpha Contamination (e.g., plutonium) from a Work Area at 233-S

   University of North Dakota Energy & Environmental Research Center http://www1.undeerc.org/scripts/ddis/ (Under "Select a Site Need ID" choose "AL-00-01-04-DD." Scroll down to "Similar Needs" to view three needs listed above.)

5. *DOE Hanford Site,* http://www.hanford.gov/

6. *Environmental Technology,* U.S. DOE Oak Ridge Operations Environmental Management Program http://www.oakridge.doe.gov/em/td/default.htm)

7. *Office of Science and Technology* [EM-50] U.S. DOE Office of Environmental Management, http://apps.em.doe.gov/ost/

8. *Research Opportunities for Deactivating and Decommissioning Department of Energy Facilities*, National Academy of Sciences/ National Research Council, 2001. (Full text available on the Web at: http://www.nap.edu/catalog/10184.html)

9. *Savannah River Site* http://www.srs.gov/general/srs-home.html

10. *Site Technology Coordinating Groups* [Links] U.S. DOE, EM Office of Science and Technology http://apps.em.doe.gov/ost/progstcg.html

11. *U.S. DOE Idaho Operations Office* http://www.id.doe.gov/doeid/index.html

12. *U.S. DOE Office of Environmental Management* http://www.em.doe.gov/


## PROGRAM AREA OVERVIEW - NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

http://www.nuclear.gov

Continued use of nuclear power is an important part of the Department's strategy to provide for the Nation's energy security, as well as to be responsible stewards of the environment. Nuclear energy research currently provides over 20 percent of the U.S. electricity generation and will continue to provide a significant portion of U.S. electrical energy production for many years to come. Also, nuclear power in the U.S. makes a significant contribution to lowering the emission of gases associated with global climate change and air pollution.

The Office of Nuclear Energy, Science and Technology (NE) enables the Department of Energy to provide the technical leadership necessary to address critical domestic and international nuclear issues by administering research and development and technical assistance in the following general areas: (1) the Nuclear Energy Research Initiative (NERI)

Program addresses key issues affecting the future of nuclear energy in order to preserve U.S. nuclear science and technology leadership, (2) the Radioisotope Power Systems Program develops new state-of-the-art radioisotope power systems to support the NASA space missions and terrestrial applications for other agencies, (3) the Nuclear Energy Plant Optimization (NEPO) Program conducts research to assure the continued safe and reliable operations of over 100 of the Nation's nuclear power plants, (4) the University Reactor Fuel and Educational Assistance Program is designed to help retain the U.S. nuclear engineering capability for conducting nuclear research, addressing pressing nuclear environmental challenges, and preserving the nuclear energy option, and (5) the Isotope Production Program produces and sells hundreds of stable and radioactive isotopes that are widely used by domestic and international customers for medicine, industry and research applications.

## 12. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power provides over 20 percent of the U.S. electricity supply without emitting harmful air pollutants, including those that may cause adverse global climate changes. New methods and technologies are needed to address key issues that affect the future deployment of nuclear energy and to preserve the U.S. leadership in nuclear technology and engineering. This topic addresses several of these key technology areas: improvements in nuclear reactor technology, computer simulation and modeling applications, and advanced thermoelectric conversion devices and materials for improved radioisotope power systems. **Grant applications are sought only in the following subtopics:**

**a. New Technology for Improved Nuclear Energy Systems**—Improvements and advances are needed for reactor systems and component technologies that ultimately would be used in the design, construction, or operation of existing and future nuclear power plants and Generation IV nuclear power systems [See References 1-5]. Grant applications are sought: (1) to improve and optimize nuclear power plant, systems, and component instrumentation and control, by developing and improving the reliability of advanced instrumentation, sensors, controls, and more accurate measurement of key reactor and plant parameters; (2) to improve monitoring of plant equipment performance and aging, using improved diagnostic techniques for in-service and non-destructive examinations; and (3) for advanced reactor/core computer simulation methods including advanced reactor design model code development; coupled/parallel thermal-hydraulic-reactor physics tools; safety and performance evaluation methods; and engineering calculations for new and existing nuclear reactors, major reactor components, and reactor core and fuel assemblies. Please note that the following areas of investigation are not of interest and will be declined: concepts for complete or partial reactor plant designs; generalized thermal-hydraulics analysis (e.g. CFD or two-fluid codes) and probabilistic risk assessment tools or methods; and NRC licensing and site permit issues. In addition, grant applications that deal with nuclear materials, chemistry, and/or corrosion research are also not of interest for this topic and should be submitted instead under Topic 13.

**b. Conversion Devices and Materials for Improved Performance of Radioisotope Power Systems**—Radioisotope Thermoelectric Generators (RTG) have been the sole electrical power systems employed for NASA deep space exploration missions such as Voyager 1 and 2, Galileo, Ulysses, and more recently Cassini [See References 1, 6-8]. These power systems provide units of power equal to nominally 100 -150 watts electrical. The RTG provide very long life reliability, but their conversion efficiencies are low, typically 6.5 to 7.5 percent when the silicon-germanium (SiGe) unicouple is used as the thermoelectric conversion device. Because of changes in mission plans and philosophy, future NASA requirements will include higher conversion-efficiency units with power levels from 50 to about 200 watts in planetary surface and deep space vacuum environments. In anticipation of these future needs, grant applications are sought to develop and demonstrate separator materials or separation devices in closed-space thermoelectric modules. The ideal separator material should have low thermal conductivity, be an electrical insulator, prevent diffusion of dopant materials, and limit the mass transfer of thermoelectric materials over the module's long operating lifetime. Approaches should focus on one of the following thermoelectric elements: (1) PbTe/TAGS (TAGS is derived from the names of the major constituents - tellurium, antimony, germanium, and silver) at a hot-side temperature of 550°C, or (2) SiGe at a hot-side temperature of 1000°C. Grant applications should also address improvements in efficiency that would result from the new materials or devices.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**References:**


1. *What's News,* U.S. DOE, Office of Nuclear Energy, Science and Technology, http://www.nuclear.gov

2. *Moving Forward: Generation IV Nuclear Energy Systems,* Office of Nuclear Energy, Science and Technology, http://gen-iv.ne.doe.gov/

3. *Nuclear Energy Research Initiative (NERI)* Office of Nuclear Energy, Science and Technology, http://neri.ne.doe.gov

4. *Nuclear Energy Plant Optimization Program (NEPO),* Office of Nuclear Energy, Science and Technology, http://nepo.ne.doe.gov/

5. Recommendations from the DOE Instrumentation, Controls and Human-Machine Interface (IC & HMI) Technology Workshop (May 15-17, 2002), IC&HMI Report. (Available on the Web at: http://www.nuclear.gov)

6. Proceedings of the Space Technology & Applications International Forum (STAIF), 1997 to date. (Available on the Web at: http://www-chne.unm.edu/isnps)

7. Proceedings of the Intersociety Energy Conversion Engineering Conferences, American Institute of Aeronautics and Astronautics, 1985 to date. (American Institute of Aeronautics and Astronautics. Telephone 703-264-7500. Web Site: http://www.aiaa.org)

8. Rowe, D. M., ed., *CRC Handbook of Thermoelectrics*, CRC Press, 1995. (ISBN: 0-8493-0146-7)


## PROGRAM AREA OVERVIEW - BASIC ENERGY SCIENCES

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

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

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

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

### 13. MATERIALS RESEARCH FOR ADVANCED NUCLEAR ENERGY SYSTEMS

The Generation IV nuclear energy initiative is an international collaboration to identify, assess, and develop sustainable nuclear energy technologies that are competitive in most markets, while further enhancing nuclear safety, minimizing the nuclear waste burden, and further reducing the risk of proliferation (reference 1). Many nuclear energy systems have been proposed to advance the goals of the Generation IV program (see



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

references 2-8), including designs that use liquid-metal coolants such as sodium and lead, gas coolants such as helium, water coolants such as supercritical water, and molten salt coolants. For these systems, operation at higher temperature has been identified as a means to improve economic performance and to support the thermochemical production of hydrogen. However, the move to higher operating temperatures will require the development and qualification of advanced materials to perform in the more challenging environment. As part of the process of developing advanced materials for these reactor concepts, a fundamental understanding of materials behavior must be established and a database that defines the critical performance limitations of these materials under irradiation must be developed. A recent workshop details many of the research challenges for higher temperature materials associated with proposed Generation IV systems (reference 9). **Grant applications are sought only in the following subtopics:**

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

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

**References:**


1. *Moving Forward: Generation IV Nuclear Energy Systems,* U.S. DOE Office of Nuclear Energy, Science and Technology, http://gen-iv.ne.doe.gov

2. Sekimoto, H., et al., *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002,* American Society of Mechanical Engineers, 2002. (Paper No. 10-22049)*

3. Wade, D. C., et al., *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002,* American Society of Mechanical Engineers, 2002. (Paper No. 10-22202)*

4. Hejzlar, P., et al., *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002*, American Society of Mechanical Engineers, 2002. (Paper No. No. 10-22377)*

5. Kiryushin, A. I. et al., "BN-800--Next Generation of Russian Sodium Fast Reactors," *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002*, American Society of Mechanical Engineers, 2002. (Paper No. ICONE 10-22405) (Available via FAX from DOE Office of Nuclear Energy, Science, and Technology. Contact Madeline Feltus at madeline.feltus@hq.doe.gov.)

6. Hittner, D., *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002*, American Society of Mechanical Engineers, 2002. (Paper No. 10-22423)*

7. King, R. L. and Porter, D. L., *Proceedings of the Tenth International Conference on Nuclear Engineering (ICONE 10), Arlington, VA, April 14-18, 2002*, American Society of Mechanical Engineers, 2002. (Paper No. 10-22524)*

8. Oka, Y. and Koshizuka, S., "Design Concept of Once-Through Cycle Supercritical-Pressure Light Water Cooled Reactors," *Proceedings of SCR-2000:International Symposium on Supercritical Water-Cooled Reactors, Design and Technology, Tokyo, Japan, November 6-9, 2000*, Tokyo: Tokyo University, July 1, 2000. (ISBN: 4-901332-00-4) (OSTI ID: 20218877) (Abstract available at: http://www.osti.gov/doeecd/. Under "Basic Search" enter OSTI ID #.)

9. Allen, T., et al., *Higher Temperature Reactor Materials Workshop Sponsored by the Department of Energy Office of Nuclear Energy, Science, and Technology (NE) and the Office of Basic Energy Sciences (BES), La Jolla, CA, March 18-21, 2002.* (Report No. ANL-02/12) (Available on the DOE Information Bridge at: http://www.osti.gov/bridge/search.results.jsp?queryId=2&start=0&)

10. Klueh, R. L. and Harries, D. L., *High Chromium Ferritic and Martensitic Steels for Nuclear Applications*, West Conshohocken, PA: American Society for Testing and Materials, 2001. (Standard No: ISBN: 0803120907)

* Abstract available at: http://www.asmeconferences.org/icone10/SearchPaperSchedule.cfm. To order proceedings see: http://www.asmeconferences.org/icone10/.

## 14. NEUTRON AND ELECTRON BEAM INSTRUMENTATION

The Department of Energy supports a number of large-scale, national user facilities that provide intense beams of neutrons and electrons for the characterization of materials. **Grant applications are sought only in the following subtopics:**

**a. Neutron Facilities**—As a unique and increasingly utilized research tool, neutrons have made invaluable contributions to the physical, chemical, and biological sciences. The Department is committed to enhancing the operation and instrumentation of its present and future neutron science facilities so that their full potential is realized.

Grant applications are sought to develop improved neutron detectors and associated electronics needed for DOE's existing and proposed steady-state and pulsed neutron scattering facilities (References 1-2, 5). New detectors must represent substantial improvements in one or more of the following parameters: efficiency at short wavelengths, high counting rate capability, high spatial resolution in one or two dimensions, cost per unit area, or adaptability to unique geometries. Detectors for pulsed neutron applications must be able to identify the time of arrival of each neutron. All detectors must have low intrinsic dark count rates and low sensitivity to gamma radiation.

Grant applications are also sought to develop novel or improved neutron optical components for use in neutron scattering instruments (References 2-3, 5). Such components include, but are not limited to, neutron choppers, neutron guides, neutron lenses and focusing mirrors, neutron monochromators, or neutron polarization devices including $^3$He olarizing filters. Applications are also sought for novel use of such components in neutron scattering instruments.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**b. Electron Beam Microcharacterization Facilities**—The Department of Energy supports four collaborative research centers for electron beam microcharacterization of materials. These tools are important in the materials and biological sciences and are used in numerous research projects funded by the Department. Innovative instrumentation developments offer the promise of radically improving the capabilities of electron beam microcharacterization and thereby stimulate new innovations in materials science. Grant applications submitted to this subtopic must address improvements in electron beam instrumentation capabilities beyond the present state-of-the-art.

Grant applications are sought to develop stages, holders, and/or detectors with new capabilities for quantifying data and collection efficiency in electron beam instruments. Areas of interest include: (1) extremely stable holders and stages that allow long exposure/analysis times, with accurate tilting and alignment capability (to an angle accuracy ±0.05 degrees on two axes while maintaining eucentricity to within 20 nm); (2) fast CCD camera systems that allow electron imaging exposure times in the millisecond range and kHz frame rates; (3) high sensitivity electron imaging systems that allow energy-filtered imaging over large areas (which may include systems based on image-plate technology or montaging, and frame-averaging software systems utilizing CCD cameras); and (4) improved electron and x-ray detectors that are robust and not susceptible to electron beam damage. Proposed approaches for electron detectors must show suitability for either low- or high-energy electrons, and address one or more of the following three aspects: high quantum efficiency, high spatial resolution, and high temporal resolution. Proposed approaches for x-ray detectors should show significant improvement in sensitivity or spectral resolution for elemental analysis in electron microscopes.

Grant applications are also sought to develop stages and holders with new capabilities for *in situ* experiments or sample manipulation in the transmission electron microscope. Stages and/or holders must provide for one or more of the following: (1) application of magnetic field up to 5000 Oe in the plane of the specimen, with capability to rotate field orientation in the specimen plane with respect to the sample; (2) manipulation or measurement of the sample using a 4-probe nanomanipulator, including capability to measure deflection or strain, or capability to apply electric fields or current; and (3) precision control of specimen temperature (to an accuracy of 10°C in the range 5-2000K), ambient gas pressure and flow rate (to within several percent for each), and alignment (to an angle accuracy ±0.05 degrees on two axes).

Grant applications are also sought to develop electron sources for scanning transmission electron microscopy with brightness on the order $10^9$ Amp/cm$^2$/steradian or higher. Current sources are based on tungsten emitters, and it is hoped that higher brightness can be achieved with new materials and designs. Proposed electron sources must be suitably robust for practical applications, have long lifetimes (greater than 6 months), and offer a significant increase in brightness over existing sources.

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

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

**References:**


1. Carpenter, J. M., et al., eds., *Neutrons, X-Rays, and Gamma Rays: Imaging Detectors, Material Characterization Techniques, and Applications, San Diego, CA, July 21-22, 1992*, Proceedings of the SPIE (International Society for Optical Engineering), Vol. 1737, Bellingham, WA: SPIE, 1993. (ISBN: 0819409103)

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

3. Majkrzak, C. F. and Wood, J. L., eds., *Neutron Optical Devices and Applications, San Diego, CA, July 22-24, 1992,* Proceedings of the SPIE, Vol. 1738, Bellingham, WA: SPIE, 1992. (ISBN: 0819409111)

4. *Proceedings of the Microscopy Society of America,* Annual Meetings, Springer-Verlag New York, Inc. (Printed version ISSN: 1431-9276) (Electronic version ISSN: 1435-8115)

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

6. Wilpert, Th., ed., *International Workshop on Position-Sensitive Neutron Detectors: Status and Perspectives, Hahn-Meitner-Institute, Berlin, Germany, June 28-30, 2001.* (URL: www.hmi.de/bensc/psnd2001)

7. *Ultramicroscopy,* 78(1-4), Elsevier-Holland, June 1999. (ISSN: 0304-3991)

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

9. Windsor, C. G., *Pulsed Neutron Scattering,* London: Taylor & Francis, 1981. (ISBN: 0-85066-195-1)

## 15. ADVANCED FOSSIL FUELS RESEARCH

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from fossil fuels. In supplying this energy need, 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 inherently clean natural gas and the Nation's most abundant and lowest cost resource, coal. **Grant applications are sought only in the following subtopics:**

**a. Natural Gas Hydrate Recovery**—Because of the widespread occurrence of gas hydrate-bearing sediments, and the enormous amount of methane stored therein (approximately 200,000 Tcf of the total U.S. methane resource of 227,500 Tcf resides in methane hydrates), gas hydrate should be considered as a potential energy resource. The natural gas industry has demonstrated that methane can be recovered from naturally occurring gas hydrates by dissociating the solid hydrates into gas and water, and then transporting the dissociated gas in the same manner as conventional natural gas. Dissociation of gas hydrates can be accomplished in at least three ways: (1) thermal (hot water) injection, in which heat is added at constant pressure until the system temperature reaches the dissociation temperature, an expensive method requiring the simultaneous movement of hot fluid downward and gas upward (without heat loss, the injected energy is about 10% of the recovered energy, but with heat loss to reservoir rock and water, the injected energy may exceed the heating value of the gas) (2) pressure reduction (depressurization), which operates by lowering the pressure in a gas reservoir with embedded or adjacent zones of solid hydrate (when the pressure reaches the dissociation pressure, gas hydrates at the interface convert to gas and water); and (3) slurry mining, which is suggestive of grinding up the ocean bottom to recover a slurry of solid hydrates that are likely to dissociate in the riser.

Although the first two methods described above have shown the most promise, none have yet been shown to be economically viable; i.e., the cost of the energy used to decompose hydrate at depth, and thereby release methane, is not significantly less than the economic value of the methane recovered. Therefore, grant applications are sought to develop viable natural gas hydrate recovery techniques. One possible approach is to inject $CO_2$ into the natural gas hydrate field in order to replace the naturally occurring methane hydrates with carbon dioxide hydrates. Because methane gas hydrates stabilize at higher pressures than $CO_2$ gas hydrates, the pressure requirement would be reduced. Also, the heat released from the formation of the $CO_2$ gas hydrate can be used to decompose the $CH_4$ gas hydrate. However, very complex phase behaviors may add to the difficulty of this process. Phase I should include thermodynamic and economic models that can be substantiated by pilot scale testing and eventually field tests in Phase II.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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

**c. Instrumentation and Sensors for Solid Oxide Fuel Cell (SOFC) Materials Science**—The use of fuel cells for power generation offers the opportunity for high efficiency and nearly pollution free operation. SOFCs consist of an ionically conducting solid oxide electrolyte layered between catalytically active porous electrodes. The electrochemically active cells are configured into a stack involving gas seals and electrical interconnections. The systems operate at high temperatures (600 to 1000°C) and suffer from chemical and mechanical stability limitations (see references 18 and 19). The search for suitable materials involves the synthesis of functional layers and interfacial regions with enhanced electrochemical properties. Unfortunately, a fundamental understanding of fabricated SOFC structures is limited by the ability to adequately characterize the functional materials in an SOFC cell and stack. Traditionally, the evaluation of SOFC materials has involved techniques such as x-ray diffraction and cross-sectional electron microscopy for structural properties (reference 15) and electrochemical impedance spectroscopy for charge conduction measurements (reference 17). However, the ultimate development of economically viable SOFCs will require more advanced measurement techniques.

Grant applications are sought to develop innovative instrumentation and sensors to advance the scientific investigation of SOFC materials. Some of the important materials parameters that require measurement include: (1) depth and/or area resolved residual stress in a layered cell, (2) ionic vacancy distributions, (3) cracks and interfacial delaminations, (4) structural and conduction continuity across interfaces; (5) porosity distributions and gradients; (6) ionic and electronic conductivity profiles; (7) catalytic activity distributions, (8) electrical conductivity and structural integrity of thin oxide films on metal interconnects, and (9) small area defect characterization (such as images of gas pinhole or electrical shorts in electrolyte layers). Of particular interest are techniques and sensors that allow for in situ measurements; pre- and post-operation non-destructive evaluation involving buried interfacial regions; and imaging techniques that can characterize spatial inhomogeneities with regard to charge transfer activity and transport, or its underlying functional materials properties. For the latter, a connection between image data sets and finite element modeling approaches should be made apparent, with the ultimate goal of validating SOFC performance models (reference 16). Grant applications also should demonstrate that the instrumentation and sensors, though focused on basic materials science, will have relevance to developers and manufacturers of optimized SOFCs.

**d. Improved Processes or New Sources for Fuels from Fossil Resources**—It is likely that the World will depend primarily on fossil fuels, especially coal, for another hundred years. At the end of 1999, two alternative processes were being developed for making liquid fuels from coal, Direct Liquefaction and Indirect Liquefaction. Since then, funding of Indirect Liquefaction has continued while further research and development for Direct Liquefaction has diminished. However, Direct Liquefaction still offers the promise of significant cost reductions through process modifications. This is because the process steps and equipment used in Direct Liquefaction are virtually the same as in the early 1970s when significant government support was first provided, namely, premix-slurry, slurry-bubble-column reactor(s), filter or critical solvent deashing, final fixed-bed polishing hydro-treater, and pressure let-down. Grant applications are sought for new or improved processes for the direct liquefaction of coal. The research and development effort should include preliminary cost estimates for a distillable product, a comparison with the costs of products from the conventional direct liquefaction process, a test of the critical steps in the process, and a demonstration of the process and its economics.

Because some parts of coal react fast and other parts react slowly, one possible approach would be to remove products from the reaction as soon as they form, in order to avoid over-reaction to refractory forms. Other

possible approaches include (see references): (1) nearly instantaneous feed coal heating to reaction temperature, at reducing conditions, by feeding it without recycle solvents; (2) exposing the partly liquefied feed coal to the reducing gas as a thin film (thereby enhancing mass transfer efficiency because each portion of the partly liquefied feed has ready access to react with the reducing gas before it degrades); and (3) allowing the carrier-reactant mass to move in slug flow to the reactor exit, while the reducing gas, flowing up through the beds, sweeps products, as they become volatile, up and out of the reactor. The latter approach would provide an opportunity for separate carrier recovery and catalyst recycle.

**References:**

**Subtopic a: Natural Gas Hydrate Recovery**


1. *National Methane Hydrate R&D Program* U.S. DOE National Energy Technology Laboratory (NETL), http://www.netl.doe.gov/scng/hydrate/index.html

2. NETL Research Focus Area: Ocean Sequestration, U.S. DOE NETL http://www.netl.doe.gov/coalpower/sequestration/inhouse.html (Scroll down page to "Ocean Sequestration)

3. Milkov, A.V. and Sassen, R. "Structurally Focused Gas Hydrate a Future Northwest U.S. Gulf Resource," *Offshore*, 61(9): 92-94, September 2001. (Available on the Web at: http://www.gasnet.com.br/artigos/artigos_view2.asp?cod=95&idio=1

4. Kvenvolden, K.A. (1995 December). A review of the geochemistry of methane in natural gas hydrate. *Organic Geochemistry*, 23(11-12), pp. 997-1008. (ISSN: 0146-6380)

5. Lee, S.Y. & Holder, G.D. (2001). Methane hydrates potential as a future energy source. *Fuel Processing Technology*, 71(1-3), pp. 181-186. (ISSN: 0378-3820)


**Subtopic b: Biogeochemical Carbon Sequestration/Conversion**


6. Beecy, D. J., et al., "Biogenic Methane: A Long-Term $CO_2$ Recycle Concept," presented at the *First National Conference on Carbon Sequestration*, May 14-17, 2001. (Available on the Web at: http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/5a1.pdf)

7. Bond, G. M., et al., "$CO_2$ Capture from Coal-Fired Utility Generation Plant Exhausts, and Sequestration by a Biomimetic Route Based on Enzymatic Catalysis—Current Status," presented at *First National Conference on Carbon Sequestration, May 14-17, 2001.* (Available on the Web at: http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/5a5.pdf)

8. Koide, H., "Prospect of Geological Sequestration for Greenhouse Gas Mitigation and Natural Gas Recovery," *International Journal of the Society of Materials Engineering for Resources*, 7(1), 1999.

9. *Putting Carbon Back in the Ground*, IEA Greenhouse Gas R&D Programme, February 2001. (ISBN: 1 898373 28 0)

10. Rice, D. D. and Claypool, G. E., "Generation, Accumulation, and Resource Potential of Biogenic Gas," *AAPG Bulletin*, 65:5-25, 1981. (ISSN: 0149-1423)

11. Schoell, M., "Multiple Origins of Methane in the Earth," *Chemical Geology*, 71:1-10, 1988. (ISSN: 0009-2541)

12. Scott, A.R., "Improving Coal Gas Recovery with Microbially Enhanced Coalbed Methane," *Coalbed Methane: Scientific, Environmental, and Economic Evaluations*, pp. 89-111, July 1999. (ISBN: 0792356985)

13. Stevens, S. and Gale, J., "Geologic $CO_2$ Sequestration," *Oil and Gas Journal*, 98(20):40-44, May 15, 2000. (ISSN: 0030-1388)

14. Wolfe, R. S., "1776-1996: Alessandro Volta's Combustible Air," *ASM News*, 62(10): 529-534, October 1996. (ISSN: 0044-7897)


**Subtopic c: Instrumentation and Sensors for SOFC Materials Science**


15. Bai, W., et al., "The Process, Structure and Performance of Pen Cells for the Intermediate

Temperature SOFCS," *Solid State Ionics*, 113-115(1-4): 259-263, December 1, 1998. (ISSN: 0167-2738) (For ordering information and to view abstract go to: http://www.elsevier.com/gej-ng//10/40/37/46/21/56/abstract.html)

16. Herbstritt, D., et al., "Modelling and DC-polarisation of a three dimensional electrode/electrolyte interface," Journal of the European Ceramics Society, 21(10-11): 1813-1816. 2001. (ISSN: 0955-2219) (For ordering information and to view abstract go to: http://www.elsevier.com/gej-ng//10/25/37/42/39/144/abstract.html)

17. Hu, H., et al., "Interfacial Studies of Solid-State Cells, Based on Electrolytes of Mixed Ionic-Electronic Conductors," *Solid State Ionics*, 109(3-4): 259-272, 1998. (ISSN: 0167-2738) (For ordering information and to view abstract go to: http://www.elsevier.com/gej-ng//10/40/37/41/22/30/abstract.html

18. Minh, N. Q. and Takahashi, T. *Science and Technology of Ceramic Fuel Cells*, Amsterdam: Elsevier, 1995. (ISBN 0-444-89568-X)

19. *Solid State Energy Conversion Alliance,* National Energy Technology Laboratory/Pacific Northwest National Laboratory, http://www.pnl.gov/energy/fuelcells/secabrochure.pdf

**Subtopic d: Improved Processes or New Sources for Fuels from Fossil Resources**

20. Callejas, M. A., and Martinez, M. T., "Hydroprocessing of a Maya Residue. 1. Intrinsic Kinetics of Asphaltene Removal Reactions" *Energy & Fuels*, 14(6): 1304-1308, 2000. (ISSN: 08870624)

21. Comolli, A.G., et al., *Low Severity Catalytic Two Stage Liquefaction Process*, U.S. Department of Energy, September 1988. (Report No. DOE/PC/80002-9) (NTIS Order No. DE89003441) (See Solicitation General Information and Guidelines, section 7.1)

22. Guin, S. A., et al., "Mechanisms of Coal Particle Dissolution," *Industrial Engineering Chemistry Research, Process Design and Development* 15(4): 490-494, 1976. (ISSN: 0888-5885) (Full text available from American Chemical Society. Web site: http://www.acs.org/. Under "Choose a page" click on "ACS Publications," then on "Journals & Magazines," and then on journal title. Type in volume & issue, select "Go" & scroll down to title.)

23. Simpson, T. B. "Improved Methods for Conversion of Our Fossil Fuels to Commercial Fuels," *Energy & Fuels*, publication scheduled for Fall 2002. (Available from author. Telephone: 301-903-3913)

24. Song, C. S., et al, "A New Process for Catalytic Liquefaction of Low-Rank Coal Using Dispersed $MoS_2$ Catalyst Generating *In-Situ* with Added $H_2O$," *Proceedings of the 14th Annual International Pittsburgh Coal Conference and Workshop,Pittsburgh, PA, September 23-27,1997*, Paper No. S08.4, Pittsburgh, PA: Pittsburgh Coal Conference, 1997. (Report No. CONF-970931)

## 16. SOLID STATE ORGANIC LIGHT EMITTING DIODES FOR GENERAL LIGHTING

Many researchers believe that solid state lighting represents an unparalleled opportunity to achieve major energy conservation in general illumination applications, with attendant benefits in pollution reduction. The development of Organic Light Emitting Diodes (OLEDs) appears to be a promising approach. However, to achieve the price ($3.00 per 1000 lumens) and performance (90 lumens per watt) required to enable the wholesale energy conservation sought in general illumination applications, quantum leaps in device performance are needed. In particular, several key technical milestones must be addressed: (1) major efficacy improvements at all wavelengths to obtain high efficiency white-light sources; (2) major cost reduction of practical device structures and form factors in order to be competitive with traditional light sources; (3) development of a new support infrastructure such as powering, fixtures, etc.; and (4) identification of new approaches to lighting enabled by OLEDs such as "smart" light sources. These and other issues have been addressed in several recent workshops sponsored jointly by the Department of Energy (DOE), the Optoelectronics Industrial Development Association (OIDA), and the National Electrical Manufacturers Association (NEMA) in collaboration with participants from industrial, academic, and national laboratories.

This topic provides small businesses with an opportunity to carry out substantially novel research and development on the fabrication, processing, and

possible approaches include (see references): (1) nearly instantaneous feed coal heating to reaction temperature, at reducing conditions, by feeding it without recycle solvents; (2) exposing the partly liquefied feed coal to the reducing gas as a thin film (thereby enhancing mass transfer efficiency because each portion of the partly liquefied feed has ready access to react with the reducing gas before it degrades); and (3) allowing the carrier-reactant mass to move in slug flow to the reactor exit, while the reducing gas, flowing up through the beds, sweeps products, as they become volatile, up and out of the reactor. The latter approach would provide an opportunity for separate carrier recovery and catalyst recycle.

**References:**

**Subtopic a: Natural Gas Hydrate Recovery**


1. *National Methane Hydrate R&D Program* U.S. DOE National Energy Technology Laboratory (NETL), http://www.netl.doe.gov/scng/hydrate/index.html

2. NETL Research Focus Area: Ocean Sequestration, U.S. DOE NETL http://www.netl.doe.gov/coalpower/sequestration/inhouse.html (Scroll down page to "Ocean Sequestration)

3. Milkov, A.V. and Sassen, R. "Structurally Focused Gas Hydrate a Future Northwest U.S. Gulf Resource," *Offshore*, 61(9): 92-94, September 2001. (Available on the Web at: http://www.gasnet.com.br/artigos/artigos_view2.asp?cod=95&idio=1

4. Kvenvolden, K.A. (1995 December). A review of the geochemistry of methane in natural gas hydrate. *Organic Geochemistry*, 23(11-12), pp. 997-1008. (ISSN: 0146-6380)

5. Lee, S.Y. & Holder, G.D. (2001). Methane hydrates potential as a future energy source. *Fuel Processing Technology*, 71(1-3), pp. 181-186. (ISSN: 0378-3820)


**Subtopic b: Biogeochemical Carbon Sequestration/Conversion**


6. Beecy, D. J., et al., "Biogenic Methane: A Long-Term $CO_2$ Recycle Concept," presented at the *First National Conference on Carbon Sequestration*, May 14-17, 2001. (Available on the Web at: http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/5a1.pdf)

7. Bond, G. M., et al., "$CO_2$ Capture from Coal-Fired Utility Generation Plant Exhausts, and Sequestration by a Biomimetic Route Based on Enzymatic Catalysis—Current Status," presented at *First National Conference on Carbon Sequestration, May 14-17, 2001.* (Available on the Web at: http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/5a5.pdf)

8. Koide, H., "Prospect of Geological Sequestration for Greenhouse Gas Mitigation and Natural Gas Recovery," *International Journal of the Society of Materials Engineering for Resources*, 7(1), 1999.

9. *Putting Carbon Back in the Ground*, IEA Greenhouse Gas R&D Programme, February 2001. (ISBN: 1 898373 28 0)

10. Rice, D. D. and Claypool, G. E., "Generation, Accumulation, and Resource Potential of Biogenic Gas," *AAPG Bulletin*, 65:5-25, 1981. (ISSN: 0149-1423)

11. Schoell, M., "Multiple Origins of Methane in the Earth," *Chemical Geology*, 71:1-10, 1988. (ISSN: 0009-2541)

12. Scott, A.R., "Improving Coal Gas Recovery with Microbially Enhanced Coalbed Methane," *Coalbed Methane: Scientific, Environmental, and Economic Evaluations*, pp. 89-111, July 1999. (ISBN: 0792356985)

13. Stevens, S. and Gale, J., "Geologic $CO_2$ Sequestration," *Oil and Gas Journal*, 98(20):40-44, May 15, 2000. (ISSN: 0030-1388)

14. Wolfe, R. S., "1776-1996: Alessandro Volta's Combustible Air," *ASM News*, 62(10): 529-534, October 1996. (ISSN: 0044-7897)


**Subtopic c: Instrumentation and Sensors for SOFC Materials Science**


15. Bai, W., et al., "The Process, Structure and Performance of Pen Cells for the Intermediate


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

characterization of solid state organic light emitting diodes (OLEDs) associated systems suitable for general lighting. To realize very large increases in performance, grant applications should be directed toward breakthrough research that offers significant advances in materials, processing, and/or characterization, ultimately leading to high-quality OLEDs capable of producing white light. Grant applications will be declined if they are limited to a minor or incremental improvement of an existing material or process. **Grant applications are sought in the following subtopics:**

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

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

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

**References:**


1. Burrows, P. E., et al., "Color-Tunable Organic Light-Emitting Devices," *Applied Physics Letters*, 69(20): 2959-2962, November 11, 1996. (ISSN: 0003-6951) (Available from American Institute of Physics. Web site: http://ojps.aip.org/aplo)

2. Shen, Z., et al., "Three-Color, Tunable, Organic Light-Emitting Devices," *Science*, 276:2009-2011 June 27, 1997. (ISSN: 0036-8075) (Available from the American Association for the Advancement of Science at: http://www.sciencemag.org/. Browse "Archives of Science.")

3. Stolka, Milan, "Organic Light Emitting Diodes for General Illumination," *OLED Solid State Lighting Workshop Report*, Washington, DC: OIDA, March 2001. (Available to OIDA members only. See *OLED Solid State Lighting Workshop Report* at: http://www.oida.org/pubs.html)

4. Tang, C. W. and Van Slyke, S.A., Chen, C. H., *Applied Physics Letters*, 65:3610 (1989). (ISSN: 0003-6951)

5. Van Slyke, S.A., et al., "Organic Electroluminescent Devices with Improved Stability," *Applied Physics Letters*, 69(15): 2160-2162, October 7, 1996. (ISSN: 0003-6951) (Available from American Institute of Physics. Web site: http://ojps.aip.org/aplo)


## 17. ENERGY STORAGE AND CONVERSION TECHNOLOGIES FOR ELECTRIC AND HYBRID VEHICLES

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

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

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

Fuel cell systems for vehicles (FCVs) require high efficiency, power density, and specific power; low cost; and automotive durability. Fuel cells systems operating on direct hydrogen must achieve by 2005, 59% energy efficiency at quarter power, 500 W/l, 500 W/kg, $125/kW, and 2,000 hours durability.

Grant applications must show how proposed innovations would result in significant advances in performance and cost reduction over state-of-the-art technologies. **Grant applications are sought only in the following subtopics:**

**a. Lithium Battery Cathode Materials with Enhanced Stability for EV and/or HEV Applications**—The instability of conventional lithium and lithium-ion cathode materials has been shown to contribute in a significant manner to the performance, calendar life, and abuse tolerance limitations of lithium-ion cells and batteries. Grant applications are sought to develop new cathode materials that meet the criteria given in the introduction and offer enhanced performance for lithium or lithium-ion batteries in EV or HEV applications. Proposed approaches must demonstrate how the particle morphologies and/or the compositional tailoring at the molecular level will enhance the performance of the novel materials in cathode structures. Of particular interest are: (1) nanophase species, used either as the active material itself or as a stability-enhancing coating; and (2) materials whose voltage profile and other properties would be compatible with a conductive polymer electrolyte. Proposed approaches must be demonstrated in full cells of at least 0.2 Ampere-hour in size.

**b. Novel Electrochemical Couples for Advanced Batteries**—New electrochemical couples offer the potential to overcome the limitations of current electrochemical systems, and to provide high-specific energy, long-life, and low-cost alternatives. Grant applications are sought to develop and demonstrate novel rechargeable couples that meet the criteria given in the introduction to this topic. Rechargeable, intercalation battery couples that incorporate anodic active materials such as aluminum or magnesium and rechargeable lithium/sulfur (Li/S) couples are of particular interest because of their potential use in high-performance, non-aqueous batteries for electric and hybrid vehicles. Areas of interest include (1) the synthesis and/or characterization of ionic conducting polymers and gel electrolytes that can transport polyvalent ions or would be suitable for use in a Li/S system; (2) development and demonstration of a method to avoid lithium dendrite formation or other deleterious electrode morphology changes in a lithium/sulfur cell; (3) development of electrolytes that are capable of conducting alkaline earth, other divalent cations, and trivalent transition metal ions; (4) development of cathodes composed of intercalation compounds that allow the rapid diffusion of polyvalent ions; and (5) development of novel non-lithium couples that do not involve a polyvalent species. Proposed approaches must be demonstrated in full cells of at least 0.2 Ampere-hour in size.

**c. Solid Electrolyte Systems for Lithium Based Batteries**—Solid electrolyte systems offer great promise for advanced batteries. Grant applications are sought to develop advanced, lithium-ion conducting solid electrolytes, along with associated manufacturing processes, capable of supporting advanced battery technologies for EV or HEV applications. Desired electrochemical properties of these systems include: ionic conductivity greater than $10^{-3}$ S/cm, electrical conductivity less than $10^{-7}$ S/cm, electrical breakdown greater than 5 volts/m, lithium ion transference number greater than 0.3, and stability of the electrolyte adjacent to a cathode material up to 5 volts versus lithium. (Note: for polymers that are single ion conductors, the above requirements may be modified suitably, provided that equivalent performance is obtained.) Desired mechanical properties include: lack of reactive plasticizer, high tensile strength, high melting point, low glass transition temperature, and high molecular weight. In addition, proposed lithium-ion conducting systems should have mass-production capability, good interface properties including compatibility and adhesion, and ambient temperature operation. Grant applications should clearly address how the proposed system would perform relative to existing polymer electrolyte systems. Phase I should focus on formulating samples of the candidate material and demonstrating that its properties are appropriate for high power systems. In order to be considered for Phase 2 funding, proposed approaches must be demonstrated in full cells of at least 0.2 Ampere-hour in size.

**d. Improved Fuel Cell Cathode Catalysts Using Combinatorial Methods**—Improved cathode structures that demonstrate higher voltage than state-of-the-art systems are needed to increase single cell voltage and reduce the number of cells in a fuel cell stack. This can be achieved by improving catalyst utilization in state-of-the-art cathodes, or by developing alternative catalyst formulations (e.g., binary and ternary alloys, non-precious metal catalysts) with improved activity. Grant applications are sought to develop or employ combinatorial methods that enable high throughput screening and testing of potential catalysts, and the identification of improved air cathode catalysts. The improved cathode performance must contribute to an overall cell performance greater than or equal to 0.5 $A/cm^2$ at 0.8 V in continuous cell operation with pressurized hydrogen and cathode loadings of 0.05 $mg/cm^2$ or less of precious metals. Targets for reformate/air operation are 0.4 $A/cm^2$ at 0.8 V, and 0.1 $A/cm^2$ at 0.85 V. These performance targets represent an order of magnitude improvement over the current state-of-the-art for Pt alloy based cells. To achieve the MEA (Membrane Electrode Assembly) cost target of $10/kW for transportation applications, the technology must have the potential to achieve total precious metal loadings (anode and cathode) of 0.2 g/peak kW, or non-precious metal loadings capable of meeting the cost target. Phase I should focus on developing and demonstrating combinatorial methods, and on identifying catalysts with significantly higher activity compared to state-of-the-art fuel cell cathode catalysts.

**References:**


1. Alper, M. D., *Complex Systems: Science for the 21st Century*, based on *A Workshop on Complex Systems, Berkeley, CA, March 5-6, 1999*, Lawrence Berkeley National Laboratory, June 23, 1999. (Report No.: PUB-826) (Available on the Web at: http://www.sc.doe.gov/production/bes/CompSystems.pdf)

2. Amatucci, G. G., et al., "Polyvalent Intercalation Batteries, a Step into Next Generation Energy Storage," presented at the *198th Meeting of the Electrochemical Society, Phoenix, AZ, October 22-27, 2000*, Abstract No. 215, *Meeting Abstracts*, Vol. MA2000-2, Electrochemical Society, 2000. (ISSN: 1091-8213) (Paper published under new title: "Investigation of Yttrium and Polyvalent Ion Intercalation into Nanocrystalline Vanadium Oxide," *Journal of the Electrochemical Society*, 148(8): 940-A950, 2001. ISSN: 0013-4651)

3. Batteries for Advanced Transportation Technologies Program, Quarterly and Annual Reports. (Available on the Web at: http://berc.lbl.gov/BATT/BATT.html) (Scroll down to bottom of page.)

4. Dagani, R., "Combinatorial Chemistry: A Faster Route to New Materials," *Chemical and Engineering News*, 77(10): 1-60, March 8, 1999. (ISSN: 0009-2347) (Title also listed as "Materials Discovery: (A Faster Route to New Materials)")

5. *Fuel Cells for Transportation*, 2001 Annual Progress Report, U.S. DOE Office of Advanced Automotive Technologies, 2002. (Available on the Web at http://www.cartech.doe.gov/research/fuelcells/index.html)

6. Landgrebe, A. R. and Klingler R. J., *Interfaces; Phenomena, and Nanostructures in Lithium Batteries: Proceedings of the International Workshop on Electrochemical Systems*, Vol. 2000-36, Pennington, NJ: Electrochemical Society, 2001. (ISBN: 1566773059)

7. Lowndes, D. H., *Nanoscale Science, Engineering and Technology Research Directions*, Oak Ridge National Laboratory, 1999. (Document No. M99-105015) (Available on the Web at: http://www.ornl.gov/~webworks/cpr/misc/105015.pdf)

8. *PNGV Battery Test Manual*, [for hybrid electric vehicles], Technical Report, Washington, DC: U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, July 1, 1997. (Report No. DOE/ID-10597) (NTIS Order No. DE98050485) (Available on the Web at: http://www.osti.gov/servlets/purl/578702-lJOESi/webviewable/)*

9. Sutula, R. A., *FY 2000 Progress Report for the Advanced Technology Development Program*, Washington, DC: U.S. Department of Energy, Office of Advanced Automotive Technologies, December 2000. (Full 77-page document available on the Web at: http://www.ott.doe.gov/pdfs/atdfy2000progressreport.pdf

10. Advanced Automotive Technology Resources and Publications Library, U.S. DOE Office of Advanced Transportation Technologies. http://www.cartech.doe.gov/ (Select either "Resources" or "Publications.")


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

11. *USABC Electric Vehicle Battery Test Procedures Manual*, Revision 2, Technical Report, Washington, DC: U.S. Department of Energy, January 1, 1996. (Report No. DOE/ID-10479-Rev.2) (NTIS Order No. DE96009671) (Available on the Web at: http://www.osti.gov/servlets/purl/214312-wzdRsH/webviewable/)*

## 18. BIOBASED PRODUCTS AND BIOENERGY

Energy from sunlight, our abundant natural resource, offers the opportunity to utilize a sustainable source of raw materials, namely, biomass from our nation's crops, forestry, aquatic, and agricultural wastes. Biomass can provide a domestic, renewable source of carbon to be used in cleaner and renewable fuels, chemicals, and power production technologies. Biomass resources include trees, forest residues, agricultural crops, crop residues such as corn stover and wheat straw, high productivity grass species such as switchgrass, and animal wastes. Its utilization can contribute to a dramatic reduction in our dependence on foreign oil, a priority goal of the Department of Energy. To this end, the Office of Basic Energy Sciences together with The Office of Energy Efficiency and Renewable Energy is seeking biotechnology research in plant sciences and processing to improve the use of bio-based renewable resources in the production of home-grown transportation fuels, chemical materials, and consumer products, and in the generation of clean, locally-based power. **Grant applications are sought only in the following subtopics:**

**a. Modification of Biomass Agronomic Traits through Plant Sciences**—Current crops, trees, and grasses offer significant potential for use as feedstock for biobased products and bioenergy. Modification of these plants can offer many additional advantages. For example, conventional commodity agricultural crops have been bred to improve productivity and disease resistance with tremendous success. The explosion of modern biotechnology and advanced molecular breeding technology offers yet far greater possibilities. Grant applications are sought to develop further improvements in agronomic traits that could greatly reduce the energy and inputs required to produce the biomass, while maintaining, or better still, increasing yields per acre. Approaches of interest include, but are not restricted to, agronomic improvements in stress tolerance, disease resistance, pest resistance, fertilizer uptake efficiency or lower fertilizer requirements, and higher yields at equal or lower input rates. All of these modifications can result in more sustainable agriculture, less energy use, and lower costs for the resulting bioproducts and bioenergy produced from the biomass.

**b. Modification of Biomass Composition through Plant Sciences**—Advances in modern biotechnology and advanced molecular breeding technology also presents opportunities for modifying the composition of the biomass plant. Modified biomass compositions could include higher amounts of desirable components that currently exist, as well as new components that are not currently produced. Ultimately, new chemicals, materials, and fuels produced directly in the biomass could result. Therefore, grant applications are sought to modify the composition of plants and trees in order to reduce the energy and cost required to produce bioproducts and biofuels. Possible approaches include modifications leading to plants that yield more carbohydrates or lipids and less lignin in their composition; plants with better fiber properties for bioproducts; plants that produce more of certain fatty acid compositions that are better suited as lubricants, polymer precursors, or other bioproducts; plants that produce new valuable chemicals or even polymers not now produced; and plants that can be taken apart into their components more easily.

**c. Biomass Gasification and Conversion to Bioproducts and Biofuels**—Biomass can be converted to synthesis gas, which consists primarily of carbon monoxide (CO), carbon dioxide ($CO_2$), and hydrogen ($H_2$), via the gasification process. Although gasification technologies have been intensely developed for two decades, resulting in both large-scale demonstration facilities and commercial units, economic problems have limited their widespread application. In the past, the products from gasification have been electricity and/or steam energy. However, the relatively low value of these products in today's market makes it difficult to justify the capital and operating costs. If gasification could be coupled with the production of higher-value liquid fuels or chemicals, a viable biorefinery could result from the combination. Grant applications are sought to further develop one of two routes, fermentation and catalytic thermochemical transformation, for the production of chemical products and liquid fuels from gasification, leading to an economically attractive opportunity.

In the fermentation route, anaerobic bacteria such as *Clostridium ljungdahlii* are used to convert CO, $CO_2$, and $H_2$ into ethanol. High conversion rates can be

obtained because the process is limited only by the transfer of gas into the liquid phase, instead of by the rate of substrate uptake by the micro-organism, which in turn limits the sugar fermentation to ethanol. Proposed approaches should further develop and improve the fermentation of syngasses to ethanol or other bioproducts.

In the catalytic thermochemical route, Fischer-Tropsch chemistry has shown that biofuels and bioproducts can be produced. To be commercially attractive, the cost of this technology must be reduced. Areas of interest include, but are not limited to, gasification gas composition and clean up, improved Fischer-Tropsch chemistry or new chemistry, better catalysts, and better more efficient reactors.

**References:**


1. *Biobased Industrial Products: Research and Commercialization Priorities (2000).* (Available on the Web at: http://books.nap.edu/books/0309053927/html/2.html#pagetop)

2. *Biomass R&D Technical Advisory Committee Recommendations*, December 2001. (Full text available on the Web at: http://www.bioproducts-bioenergy.gov/pdfs/AdvisoryCommitteeRDRecommendations.pdf)

3. *Biomass Research and Development Initiative* U.S. Department of Energy, National Biomass Coordination Office http://www.bioproducts-bioenergy.gov

4. Hardy, R. W. and Segelken, J. B., eds., *Agricultural Biotechnology: Novel Products and New Partnerships,* Report No. 8, Ithaca, NY: National Agricultural Biotechnology Council, 1996. (ISBN: 0-9630907-6-3) (Table of Contents and ordering information available at: http://www.cals.cornell.edu/extension/nabc/pubs/pubs_reports.html#nabc8)

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

6. Klass, Donald L., *Biomass for Renewable Energy, Fuels and Chemicals*, Academic Press, 1998. (ISBN 0-12-410950-0) (Available from Academic Press. Web site: http://www.academicpress.com)

7. Klasson, K. T.,et al., "Biological Production of Liquid and Gaseous Fuels from Synthesis Gas," *Applied Biochemistry and Bioengineering*, 24/25:857-873, 1990. (ISSN: 0147-0248)

8. Napier, J.A., et al., "Plant Desaturases: Harvesting the Fat of the Land," *Current Opinion in Plant Biology*, 2(2): 123-127, 1999. (ISSN: 1369-5266)

9. *Plant/Crop-Based Renewable Resources 2020*, U.S. DOE Office of Industrial Technology, January 1998. (Available on the Web at http://www.oit.doe.gov/catalog/. On menu at left, click on "Alphabetical Index." At top of page, click on "P-Q," and scroll down to title.)

10. Tengerdy R.P. and Szakács G., "Perspectives in Agrobiotechnology," *Journal of Biotechnology*, 66(2-3): 91-99, 1998. (ISSN: 0963-6048)

11. *The Technology Roadmap for Plant/Crop-Based Renewable Resources 2020,* DOE Office of Industrial Technology, February 1999. (Available on the Web at http://www.oit.doe.gov/catalog/. On menu at left, select "Alphabetical Index." At top of page, select "T," and scroll down to title.)

12. Wooley, R. J., "Meeting the Challenges of a Growing Industry," *6th Annual Renewable Fuels Association (RFA) National Ethanol Conference: Policy and Marketing, Las Vegas, NV, February 18-20, 2001.* (DOE PowerPoint presentation. For automatic download click on following URL: http://www.ethanolrfa.org/wooley.ppt)

13. Wu, R., et al., "Molecular Genetics and Developmental Physiology: Implications for Designing Better Forest Crops," *Critical Reviews in Plant Sciences*, 19(5): 377-393, 2000. (ISSN: 0735-2689)

14. Zechendorf, B., "Sustainable Development: How Can Biotechnology Contribute?" *Trends in Biotechnology*, 17(6): 219-225, 1999. (ISSN: 0167-7799)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

## 19. CATALYSIS RESEARCH AND DEVELOPMENT FOR CHEMICAL MANUFACTURING AND REFINERY OPERATIONS

Chemical manufacturing and refinery operations account for over 50% of the total global industrial process energy use. Over 80 percent of petroleum refining processes involves catalysis. About 90 percent of petrochemical manufacturing processes and more than 20% of all industrial products in the U.S. employ underlying catalytic steps. Catalysis plays a substantial role in the production of 30 of the top 50 U.S. commodity chemicals. Six more of the remaining 20 are made from raw materials that are produced catalytically. The U.S. energy use component in the production of the top 50 chemicals is significant – 5 quadrillion BTUs per year – 3 quadrillion BTUs per year for those with catalytic production routes. It has been estimated that if all the catalytic processes associated with the petroleum refining and the manufacture of the top 50 chemicals were raised to their maximum yields, total energy savings would exceed one quadrillion BTUs per year. More efficient petroleum refining and chemical production, resulting from improvements to catalytic processes, would also contribute to significantly reduced carbon emissions. This topic seeks to accelerate the catalyst discovery and applications process by identifying catalysts that have higher selectivities, can operate at modest temperatures and pressures, and contribute to a reduction in the number of unit operations, all of which impact overall resource efficiency. **Grant applications are sought only in the following subtopics:**

**a. Catalysts for Optically Active Fine Chemical Syntheses**—Many fine chemicals, used as starting materials for other chemicals (e.g., pharmaceutical manufacture, photographic chemicals, dyes and pigments), have one or more asymmetric carbons or other chiral centers that exhibit optical activity. Asymmetric syntheses, based on catalysis, is the preferred process for producing these fine chemicals because alternative processes (separating optical isomers from unwanted isomers, which are discarded and converted to desired isomers) use too much energy. However, existing asymmetric processes are inefficient. Therefore, grant applications are sought to develop new or improved catalysts – heterogeneous, homogeneous, or hybrid – for the asymmetric syntheses of optically active compounds. Reactions of interest include oxidations, reductions, alkylations, isomerizations, and substitutions such as halogen substitutions. Proposed approaches are restricted only by the following: (1) the target synthetic compounds must have commercial application, (2) the target compounds exhibit optical activity, and (3) the catalysts synthesize only one optically active isomer from starting materials that do not exhibit optical activity.

**b. Commodity Chemical Synthesis**—Oxidation is the most energy intensive of all chemical processes for the production of commodity chemicals and polymers. These commodity chemicals include ethylene and propylene oxide, styrene, phenol and acetone, and nitric acid. More selective oxidation could reduce energy consumption by increasing the yield of desired compounds. Grant applications are sought to develop catalysts and associated processes for the synthesis of olefins, aromatics, and oxygenates, the critical building blocks of these commodity chemicals.

**c. Catalysts for Petrochemical Syntheses**—The petrochemical "building blocks" (including ethylene, propylene, butane, butene, butadienes, benzene, toluene, and xylenes, and their immediate substituted products such as cumene chemicals) are used as starting materials for the manufacture of all other chemicals. Grant applications are sought for improved processes for the petrochemical synthesis of these building block chemicals (starting from petroleum fractions or natural gas liquids), based on the development of new catalysts. As an example, a catalyst used to synthesize ethylene from natural gas liquids, for example, would be of interest under this subtopic.

**d. Refinery Catalysts**—Catalysts are used in many refinery operations, including catalytic cracking, hydrotreatment, isomerization, reforming, and alkylation. Grant applications are sought to improve the above processes through the development and use of new or improved catalysts. Catalysts selected for investigation must: (1) have applicability to a U.S. refinery operation, and (2) demonstrate energy savings either by saving feedstock or by lowering operating conditions such as temperature and pressure. Small business applicants would be expected to work with a U.S. refiner, chemical company, or catalyst manufacturer in the development and application of the new or improved catalysts and applications.

*Please note: (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**References:**


1. *Technology Vision 2020: The U. S. Chemical Industry*, Washington, DC: American Chemical Society (ACS), 1996. (Available on the Web at http://www.oit.doe.gov/chemicals/visions.shtml.) (Also available from ACS. Telephone: 202-872-4386)

2. *Vision 2020 Catalysis Report.* (Available on the Web at: http://www.oit.doe.gov/chemicals/visions_catalysis.shtml.)*

3. *Vision 2020 Reaction Engineering Roadmap.* (Available on the Web at http://www.oit.doe.gov/chemicals/visions_reaction_engineering.shtml)*

4. *Vision 2020: The Materials Technology Workshop Report.* (Available on the Web at http://www.oit.doe.gov/chemicals/visions_mat_tech.shtml.)*

5. *Vision 2020: Workshop Report on Alternative Media, Conditions and Raw Materials*, a working document. (Available on the Web at http://www.oit.doe.gov/chemicals/visions_alternative.shtml)*

6. *Chemical Industry of the Future: Energy and Environmental Profile of the U.S. Petroleum Refining Industry*, U.S. Department of Energy, Office of Industrial Technologies, 2000. (Available on the Web at http://www.oit.doe.gov/chemicals/tools_profile.shtml.)*

7. *Petroleum Industry of the Future: Energy and Environmental Profile of the U.S. Petroleum Refining Industry*, U.S. Department of Energy, Office of Industrial Technologies, 1998. (Available on the Web at http://www.oit.doe.gov/petroleum/tools.shtml. Scroll down, and click on "Energy & Environmental Profile....")*


* Also available through the Office of Industrial Technologies Clearinghouse, 1-800-862-2086, or at 202-586-7543.

## 20. NANOTECHNOLOGY APPLICATIONS IN INDUSTRIAL CHEMISTRY

Many of the recent discoveries in nanotechnology, undertaken at universities and national laboratories, may have an important influence on the manufacture and uses of chemicals and materials. In this topic, small businesses are encouraged to take advantage of these discoveries and conduct further R&D that may lead to marketable products of importance to the U.S. chemical industry. The subtopic areas focus on materials research in catalysis, in polymers and polymer manufacture, in composite materials, and in new materials with special properties that mimic properties of living organisms (i.e., "biomimetics" applications). Grant applications must show an energy benefit, derived from saving energy in manufacture, conserving materials, or longer life in applications. Grant applications should also include a plan for introducing the new technology into a major chemical company with capabilities for widespread technology implementation and manufacturing. **Grant applications are sought only in the following subtopics:**

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

**b. New Nanoscale Polymer Materials, Polymer Composites, and Polymer Processes**—Recent research has shown that polymer materials with controlled nanocrystalline features may exhibit special or new properties that are not exhibited otherwise when the



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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

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

**d. Nanomaterials and Specialty Products Chemistry**—In addition to the catalysts sought in subtopic a above, grant applications are sought to develop new products, based on nanoscience and nanotechnology, for use in specialty chemicals markets. These products include adhesives, antoxidants, biocides, corrosion inhibitors, dyes, flame retardants, flavorings and fragrances, specialty coatings, surfactants, and water-soluble polymers. Grant applicants must identify (1) specialty chemicals markets that will use the new materials, (2) energy benefits to be obtained from using the new materials, (3) the basis in nanoscience for the properties of the new materials, and (4) a specialty chemicals manufacturer that is prepared to assist in the commercialization of new materials technology.

**References:**


1. *National Nanotechnology Initiative: Leading to the Next Industrial Revolution*, [Supplement to President's FY 2001 Budget], Washington, DC: NSTC/CT, IWGN, February 2000. (Full 100-page text available on the Web at: http://www.ostp.gov/NSTC/html/iwgn/iwgn.fy01budsuppl/nni.pdf

2. Roco, M. C., et al., eds., *Nanotechnology Research Directions: IWGN Workshop Report. Vision for Nanotechnology Research and Development in the Next Decade*, prepared under guidance of NSTC/CT, Baltimore, MD: Loyola College, September 1999. (Full 227-page text available on the Web at: http://itri.loyola.edu/nano/IWGN.Research.Directions) (Also available at: http://www.sc.doe.gov/production/bes/IWGN.Research.Directions/welcome.htm

3. Siegel, R. W., et al., eds. *Nanostructure Science and Technology: A Worldwide Study*, prepared under guidance of National Science and Technology Council Committee on Technology, (NSTC/CT) Interagency Working Group on NanoScience, Engineering and Technology (IWGN), Baltimore, MD: Loyola College, August 1999. (Full 336-page text available on the Web at: http://itri.loyola.edu/nano/IWGN.Worldwide.Study/


## PROGRAM AREA OVERVIEW - ENERGY EFFICIENCY AND RENEWABLE ENERGY

http://www.eren.doe.gov

The mission of the Office of Energy Efficiency and Renewable Energy (EE) is to lead the nation to a stronger economy, a cleaner environment, and a more secure future through development and deployment of sustainable energy technologies. EE sponsors technologies that protect the environment and support the nation's economic competitiveness through a program of research, development, and market deployment using private sector partnerships. EE is organized around the

four main energy users - power, industry, transportation, and buildings - an orientation that has helped the technology development programs focus on addressing the needs of the marketplace.

It is estimated that the energy technologies and practices supported by the Energy Efficiency and Renewable Energy program have saved Americans ten to fifteen billion dollars in energy costs over the past decade. These savings continue to mount as new energy technologies developed by the program for buildings, transportation, power and industry are put to use and as research continues. These energy savings are accompanied by parallel reductions in the emission of pollutants that affect human health and in the production of greenhouse gases.

## 21. NANOMATERIALS FOR ENERGY EFFICIENCY

Over the past three years the Federal government has invested nearly $1.5 Billion in nanoscience and nanotechnology – for advances in medicine and health, defense and aerospace, National security, and energy. Most of these investments have been made in Universities and National laboratories, and the supported research has primarily been basic and exploratory. This topic provides opportunities for small business to apply recent scientific discoveries in nanomaterials for technological advances in energy efficiency. The technical topics are focused on nanomaterials with potentially enhanced tribological, electrochemical, insulation, and transport properties, as well as nanomaterials that could be used for *in situ* process diagnostics and process quality control. **Grant applications are sought only in the following subtopics:**

**a. Nanomaterials for Energy Efficiency**—Grant applications are sought for nano-phase and nano-crystalline metals, ceramics, as well as mixtures of these materials, for improved wear characteristics. Applications of interest include the following: (1) materials used in industrial processes for the manufacture of glass, paper, metals, chemicals and petroleum refining or other energy-intensive materials; (2) materials used in the manufacture of high-temperature turbines; (3) materials that will increase achievable temperatures in internal combustion engines; and (4) materials with improved wear, temperature, and corrosion resistance in geothermal energy conversion and geothermal energy extraction applications. Grant applicants must demonstrate the potential for improved energy use by using these materials in their proposed applications; i.e, the performance characteristics of current technology must be identified along with the potentially improved performance characteristics of the proposed technology, including overall costs. Applicants are strongly encouraged to form partnerships with industrial equipment suppliers and end-users of the proposed technology, to achieve rapid and wide spread technology commercialization.

**b. Nanomaterials for Energy Conversion and Storage**—Grant applications are sought to develop uses for new nanomaterials in electrochemical applications. Areas of interest include the use of nanomaterials (1) in batteries, (2) as electrocatalytic materials for use in low-temperature (PEM) fuel cells, (3) as catalytic materials used for hydrogen generation or the generation of higher-value liquids or products via the reforming of fossil and renewable fuels, and (4) as materials for hydrogen storage. Performance characteristics of existing technology must be identified, and the potentially improved characteristics of the new materials must be summarized. Applicants are strongly encouraged to form partnerships with manufacturers for rapid deployment of successful new technology.

**c. Nanomaterials for In-Situ Process Diagnostics**—Nanotechnology may afford the potential for improving industrial processes and manufacturing by providing real-time information about product or process characteristics. For example, nano-crystalline material coatings could reveal temperature and quality characteristics of processed metals (such as rolled steel), thus improving process efficiency and saving energy in materials manufacture. Grant applications are sought to develop process diagnostics for potential use in the manufacture of metals, paper, chemicals, ceramics, glass, or other energy-intensive materials. Specific applications of the proposed technology must be identified, as well as the potential benefits of successful technology. Applicants are strongly encouraged to form partnerships with manufacturers and suppliers to achieve optimum commercialization of successful new technology.

**d. Nanomaterials Applications in Buildings**—Grant applications are sought for nanomaterials that could be applied to enhance the energy efficiency of buildings. Specifically, grant applications are sought for nanomaterials with potentially improved properties for

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

phase-change and other heat and humidity transfer and storage properties; electrochromic and low-emissivity windows, insulation materials, and other materials with improved energy efficiency characteristics used in building construction. Applicants must identify the potentially enhanced characteristics of the new materials, and are strongly encouraged to form partnerships with building materials manufacturers and suppliers for the commercialization of successful technology.

**References:**


1. *Clean Energy for the 21st Century*, Office of Energy Efficiency and Renewable Energy Strategic Plan, U.S. Department of Energy, 2001. (URL: http://www.nrel.gov/docs/gen/fy00/27659.pdf)

2. *National Nanotechnology Initiative: Leading to the Next Industrial Revolution*, [Supplement to President's FY 2001 Budget], Washington, DC: NSTC/CT, IWGN, February 2000. (Full 100-page text available on the Web at: http://www.ostp.gov/NSTC/html/iwgn/iwgn.fy01budsuppl/nni.pdf

3. Roco, M. C., et al., eds., *Nanotechnology Research Directions: IWGN Workshop Report. Vision for Nanotechnology Research and Development in the Next Decade*, prepared under guidance of NSTC/CT, Baltimore, MD: Loyola College, September 1999. (Full 227-page text available on the Web at: http://itri.loyola.edu/nano/IWGN.Research.Directions) (Also available at: http://www.sc.doe.gov/production/bes/IWGN.Research.Directions/welcome.htm

4. Shen, Z., et al., "Formation of Tough Interlocking Microstructures in Silicon Nitride Ceramics by Dynamic Ripening," *Nature*, 417:266-269, May 16, 2002. (ISSN: 0028-0836)

5. Siegel, R. W., et al., eds. *Nanostructure Science and Technology: A Worldwide Study*, prepared under guidance of National Science and Technology Council Committee on Technology, (NSTC/CT) Interagency Working Group on NanoScience, Engineering and Technology (IWGN), Baltimore, MD: Loyola College, August 1999. (Full 336-page text available on the Web at: http://itri.loyola.edu/nano/IWGN.Worldwide.Study/


## 22. BIOMASS

Sustainable resources will be required to provide many of the world's future needs, and biomass can play a key role in this world. For example, biomass is the only foreseeable sustainable source of food, organic fuels, and organic materials. In the U.S., biomass can provide a domestic, renewable source of carbon for use in the transportation, power, and industrial sectors, replacing petroleum as the carbon source. Biomass resources include trees, forest residues, agricultural crops, crop residues such as corn stover and wheat straw, high productivity grass species such as switchgrass, and animal wastes. Ultimately, the processing of biomass in biorefineries can result in a more sustainable biobased economy, much like that of today's petroleum economy.

Advances in enabling technologies, such as biotechnology, could be used to improve the production and use of renewable biomass resources, thereby positively impacting the rural economy and the environment. To this end, environmentally friendly technologies are sought that will enable bio-based renewable resources to produce home-grown transportation fuels, chemicals, or consumer products, and generate clean locally-based power. Grant applications must demonstrate that proposed approaches have the potential to be more economical than currently practiced technologies. **Grant applications are sought only in the following subtopics:**

**a. Advancements in Biocatalysis and Fermentation**—Plant matter is rich in carbohydrates that can be broken down into glucose and xylose, important intermediates in the conversion of biomass to chemicals and energy. However, the cost of producing these sugars, as well as the cost of converting them to chemicals and fuels, remains an obstacle to the use of biomass for industrial scale production of chemicals and energy. Cost reductions are needed to spur the development of biorefineries. The revolution in genomics, proteomics, and bioinformatics enables new approaches to biocatalysis and fermentation. Enzymes and microorganisms can be engineered to provide increases in product yield, feedstock conversion efficiency, product concentrations, and robustness in more demanding environments. New and advanced separations and purification technologies can also play an important role in reducing the cost of sugars and chemicals and fuels produced from them.

Grant applications are sought to utilize the above technologies for the optimization of unit operations that produce sugar streams from biomass and for the bioconversion of the various sugars to fuels and chemicals. Examples of sugar production technologies include improved separations and sugar recovery methods, detoxification techniques, and cellulose hydrolysis biocatalyst development and applications. Examples of sugar utilization technologies include the development of highly efficient microorganisms capable of fermenting all available sugars in the expected harsh environments of high sugar and elevated temperature, as well as the development of hydrolysate tolerant microorganisms. It may also be possible to replace whole micro-organism fermentations with enzymatic conversion of sugars to fuels or chemicals. This would require advances in enzyme stability, enzyme co-factor approaches, and potentially enzyme immobilization to facilitate product separation. Also of interest are grant applications that integrate the above-listed approaches with decreased separations requirements, in order to achieve the very high purities required for bio-derived specialty chemicals and monomers.

**b. Separation Technology for the Direct Capture of Bioproducts and Biofuels from Fermentation and Other Biotransformations or from Thermochemical Tranformations**—The U.S. chemical industry faces increasing challenges to balance the demand for continual improvements in energy and environmental performance with the equity market demand for superior financial performance. The direct capture of biobased products and biofuels from biotransformations or thermochemical transformation not only can impact these challenges, but also reduce dependence on foreign, fossil fuel-based feedstocks. Grant applications are sought to develop separation technologies to help make biomass conversions a more economically viable manufacturing process for chemicals and fuels, including but not limited to low molecular weight organic acids, organic esters, diacids or polyols, ethanol, and biobased oils, such as biodiesel and biolubricants. Areas of interest include but are not limited to: (1) approaches to reduce/eliminate fouling of membranes and ion exchange materials caused by proteins or sugars in fermentation broths, or the removal of impurities such as salts or acids that cause complications in downstream processes; (2) the development of new membrane materials that provide higher selectivity, specificity, and flux with increased stability and robustness, or modification of existing materials, such as attaching chelating groups or other modifications; and (3) the use of highly selective extraction agents with traditional solvents for improved liquid-liquid extractions, or the invention of novel reactive separation technology that combines biomass transformation with separations.

**c. Feedstock Densification and Handling**—Biomass is characterized by low bulk densities of 4-6 $lb/ft^3$ in loose form. The bulk density can be doubled to 8-12 $lb/ft^3$ when biomass is baled, and further increases to 20-30 $lb/ft^3$ are achievable by chopping and compacting the biomass to form cubes or pellets. As biomass density increases, less area and volume are required for storage, and cost reductions are achieved from the increased tonnage per transport load. Compared to bales, which are normally from one species of plant material, cubes and pellets could be premixed from a variety of feedstock. Analogous to the manufacture of animal feedstuffs, biomass compounders would be able to design and mix various feedstocks to meet quality specifications at a competitive price. Biomass compaction properties could be tailored by modifying the biomass using a variety of processes. Furthermore, bioconversion scientists have indicated that pellets and cubes could be used without modification in pretreatment (hydrolysis) processes, and smaller pellets could be introduced to boilers without regrinding. Therefore, grant applications are sought to develop innovative equipment and processes for low cost densification of biomass. The research should identify and quantify process parameters (i.e. temperatures, steam quality, pressures, and hold time) and their effect on quality of compacted material and energy requirement for compacting.

Grant applications are also sought to improve the efficiencies of existing handling systems by integrating the collection and utilization of biomass. Innovative technologies are required to develop small scale pre-treatment and/or treatment processes near feedstock sources to eliminate the need for long distance hauling and inventory. Of particular interest are small modular systems that could be moved from one source of biomass concentration to another, provided the technology could compete with more traditional technologies. Examples of candidate approaches include: (1) grinding and/or densifying biomass as fuel for furnaces to heat farm buildings for livestock, green house, and drying operations; (2) developing modular bio-oil production using fast pyrolysis process for heat and power applications; and (3) producing gas for co-generation of steam and power – the electric power generated could be used locally or to supply electricity to main power transmission lines.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**d. Drying of Biomass**—The critical moisture content for the prolonged safe storage of most agricultural products is less than 15%. For grinding and pelleting operations, biomass must have a moisture content of 10-15%. Conventional techniques for drying biomass, including in-the-field solar drying and high temperature artificial drying, are inefficient. Grant applications are sought to develop economical methods for drying biomass with high moisture content. Of particular interest is the utilization of low cost (in terms of both capital equipment and operating expense) alternate energy sources, especially heat derived from burning biomass. Possible approaches include: (1) agitating the biomass during drying to facilitate mixing of solid material and drying air (see Reference 7) – rotary drum dryers and simple fluidized bed dryers are versatile candidate processes for drying biomass; (2) flash drying for finely ground particles – however, a careful design is required to reduce the potential for fire and for dust emissions; (3) integrating commercial biomass burners with biomass dryers – depending upon combustion efficiency, the use of hot combustion gasses directly in the dryer could improve efficiencies over indirect heating through a heat exchanger; (4) recirculating exhausted air from a dryer, a process that could increase energy savings by up to 15%; and (5) reducing the airflow through pneumatic dryers, leading to further savings in energy and power. For some of the above approaches, e.g., using rotary drum dryers to handle fibrous materials, extensive literature and experience is available; however, for others, e.g. using fluidized and flash dryer systems for biomass, experience is limited.

**References:**


1. Amos, W., *Report on Biomass Drying Technology*, Golden, Colorado: National Renewable Energy Laboratory, November 1998. (Report No. NREL/TP 570-25885) (Available at: http://www.ott.doe.gov/biofuels/pedownload.html#3953)

2. Atkinson, B., and Mavituna, F., "Product Recovery Processes and Unit Operations," Chapter 17, *Biochemical Engineering and Biotechnology Handbook*, 2nd ed., Stockton Press, 1992. (ISBN: 1561590126)

3. *Biobased Industrial Products: Research and Commercialization Priorities (2000)*. (Available on the Web at http://books.nap.edu/books/0309053927/html/2.html#pagetop)

4. Biomass R&D Technical Advisory Committee Recommendations, December 2001. (Full text available on the Web at http://www.bioproducts-bioenergy.gov/pdfs/AdvisoryCommitteeRDRecommendations.pdf)

5. *Biomass Research and Development Initiative* U.S. Department of Energy, National Biomass Coordination Office http://www.bioproducts-bioenergy.gov

6. Brammer, J.G., and A.V. Bridgewater, A. V., "The influence of feedstock drying on the performance and economics of biomass gasifier-engine CHP system," *Biomass and Bioenergy*, 22(4): 271-281, April 2002. (ISSN: 0961-9534)

7. Grover, P. D. and Mishra, S. K., *Biomass Briquetting: Technology and Practices*. Bangkok, Thailand: FAO Regional Wood Energy Development Programme in Asia, 1996. (FAO Field Document No. 46) (Available on the Web at: http://www.rwedp.org/fd46.html)

8. *Jenkins, B. M., "Physical Properties of Biomass,"* Biomass Handbook, *pp. 860-891, New York: Gordon and Breach Science Publishers. (ISBN: 2881242693)*

9. Klasson, K. T., et al., "Biological Production of Liquid and Gaseous Fuels from Synthesis Gas." *Applied Biochemistry and Bioengineering*, 24/25,:857-873, 1990. (ISSN: 0273-2289)

10. Sokhansanj, S, "Through-Flow Dryers for Agricultural Crops," *Industrial Drying of Foods*, pp. 31-63, London: Blackie Academic & Professional, 1997. (ISBN 0-7514-0384-9

11. Sokhansanj, S., et al., "Characteristics of Plant Tissue to Form Pellets. Powder Handling and Processing," The International Journal of Storing, Handling, and Processing Powder. 11(12): 149-159, 1999. (ISSN No. 0934-7348)

12. *Technology Vision 2020 – The U.S. Chemical Industry,* Washington, DC, American Chemical Society, 1996. (Available on the Web at http://www.ccrhq.org/vision/index.html)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

13. Wooley, R.J., "Meeting the Challenges of a Growing Industry," 6th Annual Renewable Fuels Association/National Ethanol Conference – Policy and Marketing, Las Vegas, NV, February 18-20, 2001. (Available on the Web at: http://www.ethanolrfa.org/wooley.ppt)

## 23. NEW TECHNOLOGIES FOR GENERAL ILLUMINATION APPLICATIONS

Electricity consumed for general lighting applications in commercial and industrial buildings, residences, and outdoor applications represents more than 20% of the total U. S. electric energy production. Yet, despite concentrated efforts from both Government and industry, the efficiency of converting electric energy into visible light by commercial light sources has increased only incrementally over the last three decades. While there have been some significant recent advances in light sources, such as the compact fluorescent lamp, no truly revolutionary new light sources have been developed and commercialized since the mid 1960s. Increases in lighting system efficiency have come primarily through substitution of one type of lamp with another and from the addition of sophisticated controls. In spite of these increases in efficiency, the installed base of general illumination in US buildings is inefficient; even the most efficient of today's lighting systems convert only about 30% of electrical energy into useful visible light. Therefore, the potential for substantial increases in light source efficiency is significant, and increases in light production efficiency by a factor of two or more should be achievable. However, to realize this exceptionally high level of performance, major advancements in basic light producing technologies must be made. Within the Office of Buildings Technologies, the Department of Energy maintains an active program to explore new methods by which high quality electric light can be produced with less energy and less environmental impact. For this topic, grant applications must be directed at inorganic structures such as LEDs or hybrids – approaches that address alternate organic materials systems may be suitable for submission under Topic 16. **Grant applications are sought only in the following subtopics:**

**a. Improved Incandescent Lighting**—About 45% of the total energy consumed by electric lighting is used by incandescent lamps that produce only 14% of the total light used in the U.S. Characterized by inefficient blackbody radiation light production physics, existing incandescent lighting technology provides practical and inexpensive solutions to numerous lighting applications including many retail, residential, decorative, and specialty uses. Although energy efficient alternatives to incandescent lamps are available, it is likely that a strong market will continue to exist for simple, inexpensive, flexible light production based upon the incandescence of electrically heated filaments or conductive substrates. With existing incandescent lighting products operating at 10 to 30 lumens per watt and with system efficiencies typically less than 10%, ample opportunity exists to increase overall efficiency. Therefore, grant applications are sought to improve lighting efficiencies while still relying upon the basic incandescent process. Areas of interest include, but are not limited to, increases in efficacy produced by improved filament radiation, IR reflection, system design, and/or power conditioning. Each grant application must clearly state the anticipated increase in lamp efficacy should the project be successful. For A-Line incandescent applications, the minimum improvement must be 10% over conventional products. (For example, if a conventional incandescent lamp produces 1750 lumens at 100W of input power, a 10% increase in efficacy would yield a new product that produces either 1925 lumens at 100 watts or it may still produce 1750 lumens but consume only 90 Watts.) For specialty lamps including parabolic reflector lamps, target efficacy increases must exceed 20% over the best commercially available products. Successful proposals must result in products that can be manufactured using existing techniques without increasing production costs by more than 20%. Grant applications to replace incandescent lamps by other more efficient sources such as compact fluorescent or solid state will not be considered under this subtopic.

**b. Inorganic Solid State Lighting Materials and Manufacturing Technologies**—Many candidate inorganic materials have been examined for use in semiconductor devices that can be made to produce white light. For conventional light emitting diodes, (LEDs), traditional III-V semiconductor materials and substrates exhibit the potential to overcome certain efficiency barriers. Yet, many technical obstacles remain to be overcome before the production of very high luminous output LEDs can be manufactured at the very low costs necessary for general illumination sources. Grant applications are sought to develop new materials and associated technology that would ultimately allow for the production of solid state devices that can generate white light with at least 90 lumens per plug watt and be capable of commercial manufacture at a cost of $3.00 per 1000 lumens or less. There may be

even more efficient approaches that, when combined with novel device geometries, could provide more attractive solutions for general illumination. Possible examples include (1) hybrid materials systems that take advantage of efficient phosphor performance; and (2) novel combinations of organic dyes, polymers, and dopants with conventional inorganic compound semiconductor systems that may shift spectral outputs to more desirable regimes. Grant applications may include theoretical physical or chemical considerations of unproven systems or of the synthesis of novel compounds that promise certain performance benefits.

**c. Designs and Structures for Solid State Devices—** Existing semiconductor light producing devices may not be optimum configurations for general illumination applications. While the optical efficiency (i.e., the light extracted from the device divided by the total light produced form the semiconductor) of today's white light devices can be as low as 10%, solid state lighting products of the future will need to extract at least 90% of the visible light produced. External quantum efficiencies may be low, and other geometric optical limitations may impose performance constraints that limit overall device efficiency. High output, high color, broad spectrum, white- light-producing devices, built using current solid state technology, would cost upwards of $400 per 1000 lumen. In order to achieve economic viability and energy efficiency, grant applications are sought to develop novel designs and structures for solid state device that can be manufactured in large quantities (>1 million units per year), at low cost (less than $3.00 per 1000 lumen), and with high plug efficacy (at least 90 lumens per watt). Approaches of interest include: (1) developing alternative geometrical designs, matrices, or arrays of existing device designs to overcome problems with heat dissipation or low optical efficiency; (2) completely new device designs to achieve even more device efficiency, or (3) structures or designs that would reduce the complexity of device manufacture, either by reducing the capital costs of the specialized reactors and tooling, eliminate batch- processing by continuous processes or include more process automation. Grant applications that focus primarily on the development of novel materials should be submitted to the preceding subtopic.

**References:**

**Subtopic a: Improved Incandescent Lighting**


1. Gough, A. B., et al., *Lighting Research Bibliography*, 15-16 pages, 1997. (Available from author: Mr. Alfred B. Gough, Institute for Lighting Research, Gough & Associates, 2626 Laurel Park Hwy., Hendersonville, NC 28739. Phone: 828-692-1904)

2. Gough, A. B., et al., *Proceedings of ALITE '95 Workshop, Rochester, NY, February 28 – March 2, 1995*, Palo Alto, CA: Electric Power Research Institute (EPRI), 1995. (Report No. EPRI-TR-106022) (Available from EPRI. Telephone: 800-313-3774. Web site: http://www.epri.com)

3. *Introduction to Light and Lighting*, York, PA: Illuminating Engineering Society of North America (IESNA), 1991. (ISBN: 087995034X) (IESNA Order No. Ed-50-91) (Available from IESNA. Web site: http://www.iesna.org)

4. *Lighting Handbook: Reference and Application*, 9th ed., New York: Illuminating Engineering Society of North America, 2000. (ISSN: 1088-5102) (Publisher No. for 9th ed.: HB-9-00)

5. Murdoch, Joseph P., *Illumination Engineering: From Edison's Lamp to the Laser*, New York, NY: Illuminating Engineering Society of North America, 1994. (ISBN: 1885750005) (First edition is out of print. Copier copies may be obtained from publisher, Visions Communications in New York, NY. Telephone and fax: 212-529-4029. E-mail: bayvisions@aol.com. Second edition should be available before Spring 2003.)


**Subtopic b: Solid State Lighting Materials and Manufacturing Technologies & Subtopic c: Designs and Structures for Solid State Devices**


6. Bierman, A., "LED's: From Indicators to Illumination?" *Lighting Futures*, 3(4), Troy, NY: Rensselaer Polytechnic Institute, Lighting Research Center, 1998. (Available on the Web at: http://www.lrc.rpi.edu/Futures/LF-LEDs/index.html)

7. Jones, E. D., *Light Emitting Diodes for General Illumination, [LED Solid State Lighting Workshop Report]*, Washington, DC: Optoelectronics Industry Development Association (OIDA), March 2001. (Available to OIDA members only. See *OLED Roadmap Update 2002 and/or LED Solid State Lighting Workshop Report* on OIDA publications list at: http://www.oida.org/)*

8. Kendall, M. and Scholand, M., *Energy Savings Potential of Solid State Lighting in General Lighting Applications*, Final Report, Arlington, VA: Arthur D. Little, Inc., 2001. (Available on the Web at: http://www.eren.doe.gov/buildings/documents/pdfs/ssl_final_report3.pdf

9. Stolka, M., *Organic Light Emitting Diodes for General Illumination, [OLED Solid State Lighting Workshop Report]*, Washington, DC: Optoelectronics Industry Development Association, March 2001. (Available to OIDA members only. See *OLED Roadmap Update 2002 and/or OLED Solid State Lighting Workshop Report* on OIDA publications list at: http://www.oida.org/)

10. Stringfellow, G. B., and Craford, M. G., eds., *High Brightness Light Emitting Diodes, Vol. 48: Semiconductors and Semimetals*, San Diego: Academic Press, 1997. (Vol. 48 ISBN: 0127521569) (ISSN: 0080-8784)

## 24. SENSOR, COMMUNICATION, AND CONTROL TECHNOLOGIES FOR ENERGY EFFICIENCY

Recent advances in transduction methods, fabrication capabilities for miniaturization, high-speed/broad-band communications, and information processing and control can impact the demanding requirements for sensor/communication/control applications in energy use sectors, i.e., power generation/transmission/distribution, industry, and transportation. For example, the current radial, one-way power flow, electric grid system is being transformed into a two-way, distributive system employing central power plant generation with increased use of many "plug-and-play" distributed energy resources (DER). In such distributive generation environments, local system conditions must be sensed as feedback to local intelligent software agents to achieve optimized grid operation, while communicating and coordinating with higher-level control systems at feeders, substations, and utilities. In conjunction with local sensing/intelligent agent/control development, power electronics must be developed to control and manage two-way power flow to and from many distributive units. In the materials processing industry, the melting of raw materials and their subsequent forming into products involve high-temperature operation in which large amounts of energy are consumed. Sensors that can work in high-temperature industrial processing environments (i.e., with harsh chemicals, physical restrictions, and electromagnetic interference) will contribute significantly to minimizing waste energy and products. In the transportation sector, large-volume, low-cost production continues to be the key requirement for improved energy management technologies to achieve ultra-low emissions and high fuel efficiency. **Grant applications are sought only in the following subtopics:**

**a. Low-Cost Device for Integrated Operation of Sensing and Communications**—Grant applications are sought to develop a low-cost, single-chip, board-level or box-level device that senses and communicates data for one of the following applications: (1) local conditions at a DER-unit level, (2) $H_2$ in transportation use, and (3) fuel quality analysis. For DER, the sensing parameters must include output characteristics such as voltage, power, thermal energy, temperature, emissions, etc. The integrated device must provide functions for diagnosis, prognosis, data telemetry, data processing, and security. For $H_2$ applications in transportation, a sensor package is needed to monitor $H_2$ concentration in the feed gas to fuel cells for process control and in ambient air to assure the safety of $H_2$/air mixtures. The measurement range spans 1-100% $H_2$. At high $H_2$ concentration levels, issues associated with the potentially deteriorating effect on the oxygen pump operation must be addressed. The selectivity issue must be addressed in monitoring $H_2$ in ambient air. For fuel quality monitoring, the sensor package must determine the fuel characteristics at the point of use in residential and commercial applications and must account for both fuel degradation over time and for thermal stability. Potential sources of deterioration include dirt and water content in storage tanks, as well as biological contamination. However, water-sensing devices are not needed and should not be included in the sensor package.

**b. Distributed Intelligent Agents for Decision Making at Local DER Levels**—Grant applications are sought to develop distributed intelligent agents that are capable of detecting local faults and providing autonomous control and protection at the local DER level. These agents must provide: (1) early analysis and response to contingencies and disturbances to reduce their impact and (2) coordination with power electronics and other existing, conventional protection schemes to enhance the reliability of the grid. Additional requirements include communications with upper-level control systems, so that a coordinated response from many individual DER systems to major contingencies can be provided, and so that the overall performance of the complex network of DER systems can be achieved.

***Please note:* (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.**

This hierarchical control strategy will allow decision making from the lowest level up, with increasing sophistication and intelligence. Nested controls and intelligence at each unit level will be required for operational management for remote detection, protection, control, and contingency measures.

**c. Low-Cost, Modular, Highly Reliable Inverter**—Electric and hybrid-electric vehicle systems require an inverter to convert the direct current (DC) output of energy generation/storage systems (engine, fuel cells, or batteries) for use by support systems such as lights and air conditioning, and for AC output. For distributed energy systems, inverters provide high quality AC output for energy system demands; the inverter also returns any excess generated energy to the utility grid. However, current inverters are expensive due to cost of power electronics components. In addition, the benefits of mass production are not available since system designers must tailor the inverters to individual applications, whether vehicle or stationary. Grant applications are sought for advanced inverter packaging technology with lower cost (at least 30% compared to current inverters), reduced weight, extended lifetime (at least 10 years mean-time-between-failures), and reduced size of power electronics elements. The inverter packaging technology also must have an inherent capability of being scalable over a wide power range from 30 to 500 kW.

**d. High-Temperature Environment Applications**—Grant applications are sought to develop sensor systems for high-temperature applications in materials processing. The sensor systems must measure the distribution, or excursions from median properties, for such parameters as temperature, viscosity, and chemical homogeneity of the melt or material process flow at practical points in the process, for example, just prior to forming. Non-contact type sensors are preferred; however, contact-type sensors will be acceptable if they do not disrupt the processing environment and if they can withstand the high-temperature, erosive, corrosive environments that exist during melting, refining, and forming. The acquired property data must be displayed in an easily visualized system such as a vector wavefront similar to a velocity flow field diagram. The measurement of these properties, along with the subsequent visualizations and data representations, are essential to reduce chemical/thermal/mechanical variability at the forming point and to improve productivity.

**References:**


1. *FY2002 Annual Operating Plan: Hydrogen Program*, U.S. Department of Energy, Office of Power Technologies, October 2001. (Full text available on the Web at: http://www.eren.doe.gov/hydrogen/pdfs/31550.pdf)

2. National Research Council, *Manufacturing Process Controls for the Industries of the Future*, Washington, DC: National Academy Press, 1998. (Full text available on the Web at: http://www.nap.edu/books/0309061849/html/index.html)

3. *Office of Advanced Automotive Technologies R&D Plan*, U.S. Department of Energy, Office of Advanced Automotive Technologies, March 1998. (Available on the Web at: http://www.cartech.doe.gov/publications/index.html. Under "Option 1," input title, and click on Search.)

4. Patel, Unnati, *DG Power Quality, Protection and Reliability Case Studies Report*, General Electric Corporate R&D. Prepared for National Renewable Energy Laboratory, Golden, CO, December 2001. (Full text available on the Web at: http://www.eren.doe.gov/distributedpower/PDFs/GE_DGCaseStudies.pdf)

5. *Proceedings of the Technology Roadmap Workshop on Communication and Control Systems for Distributed Energy Resources*, U.S. Department of Energy, Office of Distributed Energy & Electric Reliability Program, September 2001. (Full text available at http://www.eren.doe.gov/der/tech_base/pdfs/cc_final.pdf)

6. *Workshop Proceedings: Communication and Control Systems for Distributed Energy Implementation and Testing*, U.S. Department of Energy, Office of Distributed Energy & Electric Reliability Program, May 2002. (Full text available at http://www.eren.doe.gov/der/tech_base/pdfs/cc_workshop_proceedings.pdf)


## 25. INNOVATIVE MINERAL PROCESSING

As one of the nine most energy intensive industries, mining consumes 1.25 quads of energy per year, or 3.3% of U.S. industrial energy use. Mineral processing accounts for approximately 37% of the energy used in

mining operations. Since 34% of the energy used in mining comes from fuel oil, reduced energy consumption in mining would also reduce demand for fuel oil. In addition to mining minerals, minerals may be recovered through recycling from other industrial processes.

Unfortunately, mineral processing generates substantial waste. The production of every ton of useful metal ore is accompanied by as much as two or three tons of waste rock that contains too few valuable minerals to warrant processing. Waste rock disposal sometimes covers hundreds or even thousands of acres and may be several hundred feet high. Furthermore, where waste is not properly managed, metals may be released from sediments into stream waters. In coal processing, the release of fine mineral particles has caused significant ecological damage. Similar problems occur in phosphate mining, where tremendous volumes of waste sand and clay must be disposed of in beneficiation processes, and in the aluminum industry, which is concerned with the disposal of massive quantities of bauxite tailings or "red mud."

New energy-efficient, waste-reducing mineral processing technologies would provide important public benefits by reducing the amount of waste generated, improving air quality, and reducing greenhouse gas emissions by reducing process energy use. In a recent workshop conducted by the mineral industry, mineral preparation, physical separations, and chemical separations were identified as key technology areas in need of research support to achieve energy and productivity savings in the next twenty years. The greatest potential improvements were thought to be associated with the optimization of combined processes and the resulting synergies. For example, combining beneficiation, dewatering, and agglomeration into a single process could reduce flow sheet complexity and materials handling.

The focus of this topic is on the development of new, more energy-efficient and waste reducing ways to process minerals rather than on emissions control, waste disposal, remediation, or treatment. (However, approaches that include materials recycling or by-product utilization will be considered.) For subtopics a, b, and c, priority will be given to research that is broadly applicable to the U.S. mining industry; optimization of the overall mining process, not only individual elements of mineral processing, is a high-level industry goal. **Grant applications are sought only in the following subtopics:**

**a. Mineral Preparation**—After extraction from the ground, minerals must be readied for direct use or further processing. Mineral preparation includes such processes as communition, makedown, classification, and drilling and blasting. Crushing and grinding of minerals alone consumes about 99 trillion Btus annually. Grant applications are sought to develop technology that can be applied during the preparation stage so that less energy is required in later processing. Possible approaches include (1) developing innovative instrumentation and sensor technology to better characterize and classify minerals; (2) combining multiple mineral preparation steps and eliminating other more inefficient ones in order to reduce the amount of energy used or waste generated across the entire mining process; and (3) improving existing structural and containment materials or developing new materials to improve wear resistance in crushing and grinding.

**b. Physical Separations**—In the mining industry, prepared minerals undergo physical separation processes including flotation, dewatering, thickening or settling, filtering, drying, flocculation, screening, magnetic separation, classification, and washing. Grant applications are sought to achieve greater system efficiencies related to the physical separation stage. Possible approaches include: (1) developing technology to increase the use of fine particles, or to separate particles to less than 5 microns, in order to reduce the amount of uneconomical mining byproducts that are generated and eventually impounded; (2) combining multiple physical separations steps and eliminating inefficient ones in order to reduce the amount of energy used or waste generated across the entire mining process; and (3) developing innovative process design and control technology (including improved sensors, systems, and empirical models) in order to provide more control over currently inefficient processes.

**c. Chemical Separations**—Chemical separations are used to isolate metals and minerals from their ore by chemical processes, including pelletizing or briquetting, smelting, refining, leaching, solvent extraction, bioleaching, and electrowinning. Grant applications are sought to develop innovative technology related to these chemical separation processes. Possible approaches include: (1) combining multiple chemical separations steps and eliminating inefficient ones to reduce the amount of energy used or waste generated across the entire mining process; and (2) developing improved reaction kinetics, improved heat efficiency, increases in direct conversion, and *in situ* recovery, which would

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

further contribute to the reduction or elimination of processing steps.

**d. Geothermal Mineral Recovery**—The recovery of minerals from geothermal brines, produced primarily for the purpose of electric power generation, also offers an opportunity for improving the economics of both power generation and mineral production. Materials of interest include borate (produced in Larderello, Italy even before electricity was generated there), carbon dioxide (available in large quantities from some geothermal fluids but not considered to be of economic interest because of its widespread availability from other sources), zinc (now being produced from geothermal brine in conjunction with electric power production at the Salton Sea 5 power plant in California), and silica (now attracting attention at several U.S. sites although product requirements, production processes, and economics have yet to be established). Grant applications are sought to develop small prototype systems for geothermal mineral recovery processing when operated on the brine flow of a geothermal power plant. The economic and operating characteristics of these processes also must be established, and the cost and quality of produced materials, as well as their markets, must be clearly defined. Commercial production of silica, manganese, hydrogen or other materials (other than zinc and carbon dioxide) associated with these geothermal fluids is desirable because an additional source of revenue from geothermal field development is provided.

**References:**


1. *1997 Economic Census Reports--NAICS Subject Sector Reports: Mining*, Washington, DC: U.S. Bureau of the Census, 2001. (Available on the Web at: http://www.census.gov/epcd/www/97EC21.HTM) (Scroll down and click on selected pdf icon)

2. Bourcier, W., et al., "Geothermal Brines," *Geothermal Resources Council Transactions*, Vol. 25, 2001*

3. Duyvesteyn, W. P., "Recovery of Base Metals from Geothermal Brines," *Geothermics (International Journal of Geothermal Research and Its Applications)*, 21(5/6): 773-799, October 1992. (ISSN: 0375-6505)

4. *Evolutionary and Revolutionary Technologies for Mining*, National Research Council, 2002. (Available from National Academy Press. Web site: http://www.nap.edu. Key in title above "Search all titles.")

5. Hudson, Travis, *Metal Mining and the Environment*, American Geological Institute, Environmental Awareness Series, 3. (Available from American Geological Institute. Web site: http://www.agiweb.org. Select "AGI Publications," then "Publications Index." Scroll down 3/4 of page and select title.)

6. Lin, M. S., et al., "Mineral Recovery: A Promising Geothermal Power Production Co-Product," *Geothermal Resources Council Transactions*, Vol. 25, 2001*

7. *Mining Annual Review 1999*, Kent, UK: The Mining Journal, Ltd., 2000. (ISSN: 0076-8995) (Available from The Mining Journal, Ltd., P.O. Box 10, Edenbridge, Kent, U.K. TN8 5NE. Web site: http://www.mining-journal.com)

8. *Mining Industry of the Future, Mineral Processing Technology Roadmap*, National Mining Association/DOE, September 2000. (Available on the Web at: http://www.oit.doe.gov/mining. Select "Vision and Roadmaps." Scroll down, and select "Mineral Processing Technology Roadmap.")

9. *Mining Industry Roadmap for Crosscutting Technologies*, National Mining Association/U.S. DOE Office of Industrial Technologies, 1999. (Available on the Web at: http://www.oit.doe.gov/mining. Select "Vision and Roadmaps." Scroll down to title.)

10. National Research Council Committee on Coal Waste Impoundments, *Coal Waste Impoundments: Risks, Reponses, and Alternatives*, Washington, DC, National Academy Press, 2002. (ISBN: 030908251X) (244-page document is available online or for purchase at: http://www.nap.edu/books/030908251X/html/)

11. Peterson, D. J., et al., *New Forces at Work in Mining: Industry Views of Critical Technologies*, Santa Monica, CA: Rand Corp., 2001. (ISBN: 0833029673) (Rand Order No. MR-1324-OSTP) ([92-page document is available online or for purchase at: http://www.rand.org/publications/MR/MR1324/


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

12. *What Mining Means to Americans*, National Mining Association (NMA). (Available from NMA. Contact: Tom Johnson, 202-463-2621)

---

* Transaction volumes available from Geothermal Resources Council. Telephone: 530-758-2360. Web site: http://www.geothermal.org.

## 26. INTEGRATED SYSTEMS FOR ENERGY-EFFICIENT SPACE CONDITIONING

Significant advances in the state-of-the-art in building envelope components and in heating, ventilating, and air-conditioning (HVAC) systems for residential buildings have taken place over the past two decades. With the exception of high velocity air distribution systems, these advancements in HVAC systems are marketed for new homes. However, existing residential buildings are often 30% less efficient than new buildings, and $15 billion worth of energy is wasted each year because the older HVAC systems were poorly installed or have degraded with time. Therefore, great potential exists to improve the energy efficiency and thermal comfort in existing homes. An important area of opportunity is systems integration, in which two or more parts of the HVAC system are optimized and in which improved control can maintain the entire system efficiency. **Grant applications are sought only in the following subtopics:**

**a. Separate Dehumidification and Ventilation with an Outside Air Economizer for Residential HVAC Systems**—Recent research indicates that 30% improvements in space cooling efficiency, currently at 10 to 12 SEER (Seasonal Energy Efficiency Ratio), could be achieved by separating the functions of dehumidification and cooling in the HVAC system. Grant applications are sought to design and develop an equipment package that provides separate dehumidification and ventilation subsystems, uses an outside air economizer, and can be integrated with an existing air conditioning system. The dehumidifier would require a capacity of 36 to 65 Liters/day, an energy efficiency of at least 2.8 Liters/Kwh, and the ability to reject heat to the outside air. The ability to pre-cool and dehumidify ventilation air, and to allow the use of an outside air economizer cycle when outside temperatures are below the inside temperature, are also required. These concepts will require an equipment package that operates at some times on the ventilation air or outside air economizer only, on recirculated air plus ventilation air at other times, and on recirculated air only. A high efficiency air filtration system also would be a valuable optional accessory. Collaboration with a builder/contractor is encouraged to facilitate adoption of the technology within the industry. The system should be tested in actual houses to demonstrate its energy savings potential. The system should be sized consistent with a 3-ton air conditioning system and should be capable of dehumidifying 100 CFM of outside air at 90°F and 70% relative humidity to 72°F and 50% relative humidity indoor conditions.

**b. Sealing and Insulating Existing Residential Air Distribution Systems**—Duct losses in existing air distribution systems can amount to 30% or more of the input energy. Careful attention to installation and specification of highly insulated (R=8 or better) ducts can prevent these losses in new installations, but there are few cost effective ways to improve existing ducts. Grant applications are sought to develop a simple, low-cost approach to seal and insulate air distribution systems in existing homes. Possible approaches include a duct wrapping or duct lining system that would both seal and insulate existing ducts. The system should be easy and foolproof to install and must not degrade over time, which is a problem for systems that use taped connections because the adhesive on duct tape fails quickly. Proposed approaches must be consistent with environmental conditions that include high humidity, high and/or low temperatures, and high air pressure inside the duct. Adaptability to various types of duct materials (metal, plastic, duct board, flexible ducts, etc.) is also required. Teaming with an HVAC installation contractor would be a significant advantage for marketability and ease of installation. The proposed system should be tested in actual houses to determine the extent of air sealing and insulation achieved. The resulting sealed duct system should demonstrate lower leakage than the currently installed system, permitting no more than 10% leakage of total airflow at 25 Pa pressure.

**c. HVAC Diagnostic System Integrated with Temperature and Humidity Control for Residences**—Current central air conditioning systems tend to be over or undercharged more than 70% of the time, resulting, on the average, in a 12% increase in energy use. Current air conditioning controls are based only on temperature, and provide no information on the status of the refrigerant charge or system airflow. Additionally, the temperature control may force a homeowner to set the temperature lower than desirable

to obtain sufficient dehumidification during humid weather, resulting in unnecessary overcooling. Grant applications are sought for a low-cost controller that provides an HVAC diagnostic capability with indicator readouts and controls both humidity and temperature in residential heating and air conditioning systems. The HVAC diagnostic system should sense high or low refrigerant charge and system airflow and notify the homeowner via indicator readouts on the HVAC controller. The controller must sense and control humidity and temperature, determine the status of refrigerant charge and airflow, and provide readouts for these parameters. The control functions should be accurate to with 2°F and 3% relative humidity. The diagnostic functions should be able to identify a 10% change from correct refrigerant charge and airflow. Also, a ventilation sensing and control cycle would be a valuable optional function; such a control might run the indoor fan and the compressor on low speed to obtain the desired dehumidification without excessive temperature reduction. Laboratory and field evaluations should be included as part of the research project.

**References:**


1. Andrews, J., *Better Duct Systems for Home Heating and Cooling*, Brookhaven National Laboratory, January 2001. (Report No. BNL-68167) (Available on the DOE Information Bridge at http://www.osti.gov/bridge/search.easy.jsp. Search "Bibliographic Info" for "bnl-68167.")

2. Neme, C., et al., *Energy Savings Potential from Addressing Residential Air Conditioner and Heat Pump Installation Problems*, American Council for an Energy-Efficient Economy, February 1999. (Available from American Council for an Energy-Efficient Economy. Telephone: 202-429-0063. Web site: http://www.aceee.org/pubs/a992.htm)

3. Walker, I. S., *Sensitivity of Forced Air Distribution System Efficiency to Climate, Duct Location, Air Leakage, and Insulation*, Lawrence Berkeley National Laboratory, 2001. (Report No. LBNL-43371) (Available on the Web at: http://epb1.lbl.gov/. In the purple menu, select "Publications." Under "Residential Buildings," select "Thermal Energy Distribution-Ducts." Scroll down to "Walker, I. S. 2001...LBNL 43371.")

4. Walker, I., et al., *Leakage Diagnostics, Sealant Longevity, Sizing and Technology Transfer in Residential Thermal Distribution Systems*, Lawrence Berkeley National Laboratory, January 1998. (Report No. LBL-41118) (Available on the Web at: http://epb1.lbl.gov/. In the purple menu, select "Publications." Under "Residential Buildings," select "Cooling Systems." Scroll down to "Walker, I....LBL 41118."


## PROGRAM AREA OVERVIEW – FOSSIL ENERGY

http://www.fe.doe.gov/

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

Technological innovation is required to take advantage of the United States' large supply of coal and natural gas reserves. Coal's major drawback is that it contains sulfur, nitrogen, and trace heavy metals, precursors of pollutants that could have deleterious effects on the environment. Natural gas is also produced with a wide variety of pollutant-forming compounds, which preclude some applications such as fuel cells and advanced gas turbines. For both coal and natural gas, further improvements are needed to develop advanced, low cost, high-efficiency processes for the production of clean energy. In addition, it is prudent to consider ways to reduce carbon dioxide and other greenhouse gases that are generated by the combustion of fossil fuels, and to mitigate impacts on water resources. Advanced technology development in materials

utilization and recovery will be needed for these challenges - as well as innovations in sensors, electronics, and controls - to be commercially competitive.

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

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

## 27. MEASUREMENT AND TECHNOLOGY FOR GASIFIERS

To sustain our economic growth, we need to utilize our most abundant fossil energy resources, coal and natural gas, efficiently and environmentally safe. The Department of Energy (DOE) is supporting the development of advanced technology power plants that offer higher efficiency, lower emissions, and reduced capital and operating costs. The "Vision 21" concept is a new approach to the production of energy from fossil fuels in the 21st century. It will integrate advanced concepts for high-efficiency power generation and pollution control into a class of fuel-flexible facilities capable of operating with near zero environmental emissions. The approach includes a variety of configurations to meet differing market needs, including both distributed and central generation of power. The development and optimum performance of advanced coal gasifiers will be critical to the success of this program. This topic seeks to develop key support technologies and measurement techniques for these gasifiers. **Grant applications are sought only in the following subtopics:**

**a. Temperature Measurement in Gasifiers**—Grant applications are sought to develop robust temperature measurement systems suitable for use in high-temperature coal gasifier applications. These measurement systems must: (1) consist of the actual temperature measurement device along with the protection system used to isolate the measurement device from the harsh operating conditions found within the coal gasifier; (2) operate at temperatures up to 1600 C, in flow conditions containing granular carbonaceous materials, sticky or molten ash, and in the presence of gases containing significant quantities of methane, water vapor, carbon monoxide, hydrogen, and low concentrations of alkali metals, hydrogen sulfide, hydrogen chloride, and ammonia; (3) withstand the mechanical stresses generated by the high gasifier temperatures, the high temperature gradients found across the refractory liners, and the chemically corrosive atmosphere found within the gasifier; and (4) be capable of surviving continuous gasifier operation for at least one year.

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

**References:**


1. Clayton, S. J., et al., "Gasification Markets and Technologies--Present and Future: An Industry Perspective," National Energy Technology Laboratory (NETL) U.S. Department of Energy, July 2002. (Report No. DOE/FE-0447) (Available on the Web at http://www.netl.doe.gov/coalpower/gasification/ On menu at left select "Ref. Shelf." In Table of Contents select "Publication/Reports," and scroll down to title.)

2. *DOE Fossil Energy Techline* U.S. DOE Office of Fossil Energy http://www.fe.doe.gov/techline/tl_gastemp.html


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

3. Dogan, C. P., et al., "Improved Refractories for IGCC Power Systems," presented at the *16th Annual Conference on Fossil Energy Materials, Baltimore, MD, April 22-24, 2002.* (Full text available at: http://www.netl.doe.gov/publications/proceedings/02/materials/Dogan02.pdf)

4. *Gasification Technologies,* U.S. DOE NETL http://www.netl.doe.gov/coalpower/gasification/index.html

5. *Gasification Technologies,* U.S. DOE Office of Fossil Energy http://www.fe.doe.gov/coal_power/gasification/index.shtml

6. Mann, M. D., "Dynamic Testing of Gasifier Refractories," *Proceedings of the University Coal Research Contractors Review Meeting 2002, Pittsburgh, PA, June 4-5, 2002*, U.S. DOE NETL, 2002. (Full text available at: http://www.netl.doe.gov/publications/proceedings/02/ucr/Mann_UCR%20abstract.PDF)

## 28. MATERIALS, SENSORS, AND CONTROLS FOR ADVANCED POWER SYSTEMS

New materials, ideas, and concepts are required to significantly improve performance and reduce the costs of existing fossil systems or to enable the development of new systems and capabilities. The Fossil Energy Materials Program conducts research and development on high-performance materials for longer-term fossil energy applications, including high-temperature/high-pressure heat exchangers, hot gas filtration systems for removing particulate matter formed during coal combustion and coal gasification, gas separations, high-temperature fuel cells, and advanced turbine systems. The Sensors and Controls Program seeks to provide the power industry with advanced sensors and controls to increase operational efficiency, reduce emissions, and lower operating costs. Concurrent with developments in power generation technology, advancements in robust sensing and control algorithms can accelerate the time to full-scale commercial implementation of new power systems. Both programs are concerned with operation in the hostile conditions created when fossil fuels are converted to energy. These conditions include high temperatures, elevated pressures, pressure oscillations, corrosive environments (reducing conditions, gaseous alkali), surface coating or fouling, and high particulate loading. **Grant applications are sought only in the following subtopics:**

**a. Hydrogen Separation Membranes**—Ceramic membranes offer significant advantages over other membranes; they show greater stability under the Integrated Gasification Combined Cycle (IGCC) operating conditions and are likely to have a higher resistance to attack by the flue gas. In addition, the separation of streams of hydrogen and carbon dioxide in IGCC by ceramic membrane technology is more efficient than other separation technologies. Two types of ceramic membranes are being investigated for the recovery of hydrogen from coal gasification streams: porous membranes and dense membranes. These membrane types differ significantly in their microstructures, and, therefore, gas separation takes place by entirely different hydrogen diffusion mechanisms as described below. Grant applications are sought to further the development of either or both types of these ceramic membranes for commercial hydrogen production. Proposed approaches must demonstrate that the hydrogen can be produced in large quantities and at high purity; therefore, both the permeation properties and the selectivity of the membranes must be well characterized and understood.

In porous membranes, hydrogen is transported through the pores as molecules and the process occurs readily. The separation membrane is usually made from silica and/or alumina supported by a highly porous ceramic layer. Porous membranes are being designed to operate at temperatures in the region 300-400°C to be compatible with IGCC integration. Currently, the maximum operating temperature for these membranes is 300°C, although even at this temperature, there are concerns with stability in $H_2O$-containing atmospheres.

In dense membranes, hydrogen is transported in the solid phase as hydrogen ions (protons). In principle, these membranes can produce very high purity hydrogen because only hydrogen is transported through the membrane. The materials of interest for dense membranes are those that show high protonic conductivity, such as doped $SrCeO_3$ and $BaCeO_3$. Transport in the solid phase requires more thermal energy than gas phase transport and hydrogen fluxes comparable to those obtained from porous membranes are only achievable at much higher temperatures, typically around 900°C. Unfortunately, dense ceramics have not yet been demonstrated to be compatible with gasification systems operating at 900°C, because contaminants in the gas adversely affect the membrane. Therefore, one area of interest is the development of dense membranes that can resist the contaminant effects.

**b. Turbine Coatings Development**—Protective coatings play a key role in permitting higher-temperature operation of advanced gas turbines and in extending their service life. These coatings are broadly categorized as thermal barrier coatings (TBCs) and environmental barrier coatings (EBCs), depending on their primary function. In the past, the designs for these coatings, especially TBCs for single crystal (SX) turbine blades, were developed through a phenomenological approach. However, today, emphasis is on prime-reliant design (i.e., providing the designer with safe performance criteria) based on sound mechanistic knowledge of gas-solid interactions at high temperatures, and of the way in which these interactions influence the processes involved in degradation during service. Grant applications are sought to develop high-temperature protective coatings for gas turbines used in a coal-derived synthesis gas (syngas) system. The aim is to identify physically attainable limits and to push the operating envelope to that point through prime reliant design. Proposed approaches for the coatings should demonstrate low thermal conductivity, adhesion, and survivability under operating conditions. Areas of interest include coatings for turbines based on both SX alloys and ceramics. For metallic substrates, separate coating layers may be required for the environmental and thermal barrier functions, whereas for ceramics, it may be possible to fulfill both roles in a single coating layer. Also of interest are manufacturing/coating processes that are airfoil-specific – e.g., coatings for vanes may be different than those for blades (different property/thickness requirements lead to different coating processes, etc.).

Grant applications are also sought to understand how trace contaminants in the syngas interact with advanced turbine blade materials and coatings, an interaction that may be compounded by synergistic effects between various degradation processes. Depending on the type of gasifier and its hot gas environment, these degradation processes include deposition, erosion, or corrosion from heavy metals or particulates, or from such gaseous species as SOx, alkali compounds, or HCl. There is a dearth of long-term performance data for these environments, yet the above degradation processes, as opposed to creep and fatigue processes, are likely to limit the life of gas turbine hot gas components (e.g. combustion chamber, vanes, and blades). One possible approach is the development of hot corrosion and erosion-corrosion models to predict the lives of candidate gas turbine hot-gas-path materials in realistic environments and to determine how changes to these environments or configurations (e.g., materials/coatings combinations) could significantly extend these lives. Priorities include the selection and verification testing of turbine hot path component materials and protective coatings.

**c. Ultra-High Temperature Intermetallic Compounds**—Materials based on the Mo-Si system offer the potential for the use of metallic structures at temperatures well above 1000°C, perhaps up to 1500°C. Significant progress has been made in the development of these alloy systems to suggest that properties can be achieved that will allow them to be used in engineering applications. Therefore, grant applications are sought to develop new-generation corrosion-resistant Mo-Si alloys for use as hot components in advanced fossil energy conversion and combustion systems. The successful development of Mo-Si alloys would be expected to increase the service life of hot components exposed to corrosive environments at temperatures up to 1500°C, thus enabling the development of components for high efficiency power systems. Of particular interest are alloy systems such as Mo-Si-B. For example, boron-modified $Mo_5Si_3$, which exhibits excellent oxidation and creep resistance, as well as a high melting point, is an attractive candidate for structural uses up to 1600°C. The phase, $Mo_5SiB_2$ (T2-phase), is also of interest because, by providing a source of boron, oxidation resistance would be enhanced.

Grant applications are also sought to develop processing technology for these alloys in order to achieve appropriate microstructures, capable of yielding alloys with sufficient fracture toughness for engineering applications. For example, a suitable microstructure might contain an essentially continuous molybdenum matrix; however, casting is unlikely to deliver such microstructures. Instead, innovative processing approaches for these materials are needed so that useful product forms can be produced while maintaining a structure that has adequate fracture toughness.

**d. Sensors And Controls For Advanced Power Systems**—Concurrent with developments in power generation technology (advanced combustion, gasification, turbines, and fuel cells) revolutionary advancements in robust sensing technology are needed to overcome the harsh conditions that exist when converting fossil fuel to energy. These conditions include high temperatures (500-1500°C), elevated pressures (200-400 psi), pressure oscillations, corrosive environments (reducing conditions, gaseous alkali), surface coating or fouling, and high particulate loading. Grant applications are sought to develop: (1)

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

microsensors designed with or fabricated using high temperature substrates and materials, including but not limited to silicon carbide, alumina, or sapphire – for these microsensors, the minimum temperature for sensor testing is 500°C; and (2) miniaturized and ruggedized laser or optically based systems designed to interface with high pressure, high temperature systems – for these systems, the design must maintain proper access or a clear sight path. Proposed sensors or systems should address the *in situ*, real-time monitoring of one or more of the following: surface and gas path temperature in syngas turbines, gas composition analysis (e.g., $H_2$, CO, low molecular weight hydrocarbons) to assess system performance, and emission monitoring (e.g. NOx, Hg). Other factors (accuracy, reliability, longevity, calibration or validation, and cost) that increase the risk of developing commercially viable sensors and controls should also be addressed in the grant application. Approaches that focus on extractive systems or that are for incremental advancements in measurement technology are not of interest and will be declined.

**References:**

**Subtopic a. Hydrogen Separation Membranes**


1. Benson, S., *Ceramics for Advanced Power Generation*, London: International Energy Agency (IEA) Coal Research, August 2000. (ISBN: 92-9029-349-7) (Available from IEA Coal Research. Online synopsis and ordering information: http://www.iea-coal.org.uk/publishing/generation/ccc37.htm)

2. Norby, T. and Larring, Y., "Mixed Hydrogen Ion-Electronic Conductors for Hydrogen Permeable Membranes," *Solid State Ionics*, 136-137:139-148, November 2000. (ISSN: 0167-2738)


**Subtopic b. Turbine Coatings Development**


3. *Gasification Technologies,* U.S. DOE National Energy Technology Laboratory (NETL) http://www.netl.doe.gov/coalpower/gasification/index.html

4. Rebillat, F., et al., "The Concept of a Strong Interface Applied to SiC/SiC Composites with a BN Interphase," *Acta Materialia*, 48(18-19): 4609-4618, December 2000. (ISSN: 1359-6454)

5. Simms, N. J., et al., "Erosion-Corrosion Modelling of Gas Turbine Materials for Coal-Fired Combine Cycle Power Generation," *Wear*, 186-187(Part 1): 247-255, July 1995. (ISSN: 0043 1648)

6. Tzimas, E., et al., "Failure of Thermal Barrier Coating Systems Under Cyclic Thermomechanical Loading," *Acta Materialia*, 48(18-19): 4699-4707, December 2000. (ISSN: 1359-6454)


**Subtopic c: Ultra-high Temperature Intermetallic Compounds**


7. Natesan, K. and Deevi, S. C., "Oxidation Behavior of Molybdenum Silicides and Their Composites," *Intermetallics*, 8(9-11): 1147-1158, September 2000. (ISSN: 0966-9795)

8. Parthasarathy, T. A., et al., "Oxidation Mechanisms in Mo-Reinforced $Mo_5SiB_2$ (T2)-$Mo_3Si$ Alloys," *Acta Materialia*, 50(7): 1857-1868, April 2002. (ISSN: 1359-6454)

9. Schneibel, J. H., "Mo-Si-B Alloy Development," *16th Annual Conference on Fossil Energy Materials, April 22-24, 2002.* (Available on the Web at: http://www.netl.doe.gov/publications/proceedings/02/materials/schneibel19apr02.pdf)


**Subtopic d: Sensors and Controls for Advanced Power Systems**


10. Boyce, M. P., "Advanced Condition Monitoring for Advanced Gas Turbines," Proceedings from EPRI/DOE International Conference on Advances in Life Assessment and Optimization of Fossil Fuel Power Plants, Orlando, FL, March 11-13, 2002. (EPRI report no. for proceedings: 01006965) (Proceedings available from EPRI Order and Conference Center. Telephone: 800-313-3774; select option 2)

11. Instrumentation, Sensor, and Control Systems Program Plan, U.S. DOE NETL – Power Systems Advanced Research, (Available from NETL. Contact: Susan Maley at susan.maley@netl.doe.gov)

12. Kilgroe, J. D. and Srivastava, R. K., "EPA Studies on the Control of Toxic Air Pollution Emissions from Electric Utility Boilers," *Journal of Environmental Management*, 61(1) 30-36, January 2001. (ISSN: 0301-4797)

13. Lowndes, D. H., et al., *Nanoscale Science, Engineering and Technology Research Directions*, U.S. Department of Energy, Office of Basic Energy Sciences/Oak Ridge National Laboratory. (Contract No. DE-AC05-96OR22464) (Available on the Web at: http://www.sc.doe.gov/production/bes/nanoscale.html)

14. Ravel, M., "Sensing for Smart Systems", Proceedings from IIEEE/ISA Sensors for Industry Conference, SIcon/01, Rosemount, IL, November 5-7, 2001. (ISBN 0-7803-6659-X) (IEEE Catalog No. 01EX459)

15. *Sensors and Control Workshop Summary Report,* U.S. DOE NETL, Power Systems Advanced Research Program, http://www.netl.doe.gov/publications/reports/2001/S&C%20wkshp%20rpt.pdf

16. *Vision 21 Technology Roadmap,* U.S. DOE NETL, http://www.netl.doe.gov/coalpower/vision21/index.html

## 29. FUEL CELL RESEARCH

The objective of the Fuel Cell Program is to conduct research and development on processes and materials to speed up the deployment of the technology. The focus is on research leading to a scientific understanding of high-performance materials compatible with fuel cell environments and to generate new materials, ideas, and concepts that have the potential to significantly improve performance or cost over what is currently available. Consequently, developing improved materials for hydrogen production and storage, high-temperature fuel cells, and solid state electrochemical materials constitute major objectives of the program. **Grant applications are sought only in the following subtopics:**

**a. Solid State Electrochemical Materials for Advanced Power Applications Related to Hydrogen Production and Storage**—Electrolytic membranes fabricated from ionically conducting solid state materials have been used effectively in solid oxide fuel cells (SOFCs) for electricity generation from hydrogen gas. Current SOFC research includes catalytic optimization of electrode charge transfer, reduction in electrical resistance of cell components, and improvement in materials fabrication techniques. Another promising area of research involves the use of SOFCs in applications involving both energy conversion and fuel processing. For example, electrolyzers could be used at distributed locations to create hydrogen from either hydrocarbon fuels or grid based electrical power. Such "reversible" fuel cells could convert electrical energy for storage in intermediate chemical fuels during times of low power demand and then reproduce electrical energy during peak demand periods, providing an important demand leveling function.

Grant applications are sought to develop materials that are tailored to the reversible production of hydrogen or other intermediate fuels using SOFC-related technology. One area of research interest is the reversibility of realistic electrode materials and their impact on reversible SOFCs and electrolytic fuel processing. Charge transfer and mass transport at the electrodes, under conditions where fuel gases are evolved rather than consumed, require investigation. When state parameters are kept constant and conditions are close to equilibrium, the mechanisms for electrochemical charge transfer are independent of reaction direction. However, with electrolysis, for example, high volume operating conditions may be such that the kinetics (and even the mechanistic reaction steps) for the oxidation of oxygen (ion to gas) might be significantly different than for the reduction of oxygen (gas to ion) at SOFC cathodes. Catalysts and microstructures that promote efficient charge transfer in one reaction direction may need to be redesigned or optimized for efficient kinetics of the reverse reaction. Similar issues involving the reversibility of the hydrogen reactions may also need to be resolved.

**b. High-Temperature Net-Shape Insulation Material**—Insulation is an important cost factor in solid oxide fuel cells (SOFCs) and SOFC-turbine hybrid systems; as other SOFC costs decrease, expenses associated with insulation fabrication and assembly become more significant. Therefore, grant applications are sought for research leading to the development of high-temperature ceramic materials and associated net-shape fabrication techniques, resulting in lower cost insulation for the operation of SOFCs used in power generation systems. Insulating materials for SOFC applications must be thermally, structurally, and chemically stable within both the oxidizing and reducing environments of SOFC systems. The insulation materials must be capable of long-term service (greater than 50,000 hours) at temperatures up to 1000°C, must remain inert and resistant to oxidation, and must not emit any compounds that poison or degrade SOFC performance. (For example, when used in the high-temperature fuel environment, low-grade alumina insulation has been found to evolve SiO, which migrates to the anode where it interacts and degrades the power generation performance of the SOFC device.)

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

Regarding fabrication, insulation for current prototype SOFC power generation systems is generally pieced together from sheet stock, a labor intensive method that produces less-than-optimal insulation. The cutting process compromises any gas barrier properties of the sheet stock surface and creates gas permeation paths that affect system isolation, leading to hydrogen/insulation interactions. Therefore, manufacturing techniques that produce appropriately shaped insulation parts without extensive machining and post-processing are of particular interest.

**c. Fabrication of Solid Oxide Fuel Cell Structures via Spray Deposition**—Recent advances in the spray deposition of ceramic materials may enable the production of certain solid oxide fuel cell (SOFC) structures at substantially lower cost than with current fabrication methods. However, significant technical challenges must be addressed before widespread industrial acceptance of spray deposition in high-volume mass production is possible. Grant applications are sought to improve the quality and bonding of spray-deposited SOFC layers while also substantially lowering energy costs and materials waste during deposition. Specific areas of improvement include:

(1) Effective material utilization. Current fabrication systems tend to lose up to 70% of the spray material due to over-spray. The lack of low cost methods for recycling the over-spray material inhibits the economic viability of mass production with spray deposition techniques. Improved techniques that diminish the material lost by over-spray will improve the cost competitiveness of the process.

(2) Reduced gas leakage through the electrolyte, leading to localized combustion and the eventual catastrophic failure of the fuel cell. Because spray deposition techniques do not generally lead to optimally dense electrolyte films without additional sintering, greater electrolyte thicknesses are required to achieve a gas-tight barrier between the cathode and anode. The production of thin (5 to 10 micron) yet dense (greater than 95%) electrolyte layers without significant post deposition thermal processing is needed.

(3) Microstructures with tailored porosity. Prior research has determined the optimal electrode microstructures for SOFC operation at high power densities. New spray deposition techniques must be capable of repeatedly producing the designed microstructure and porosity while achieving quality bonds between layers. Spray deposition technologies that allow for the control of SOFC microstructural properties are of particular interest.

Processes with broad SOFC applicability are sought; approaches that focus on producing a specific cell design are not of interest and will be declined.

**References:**

**Subtopic a: Solid State Electrochemical Materials for Advanced Power Applications Related to Hydrogen Production and Storage**


1. Larminie, J. and Dicks, A., *Fuel Cell Systems Explained*, West Sussex, England: John Wiley & Sons, Ltd., June 2000. (ISBN: 0-471-49026-1)

2. *Solid State Ionics* or *Journal of Power Sources*, Elsevier Science. (For article titles and ordering information, see: http://www.sciencedirect.com/science/publications/journal/)

3. *Solid State Energy Conversion Alliance* U.S. DOE Electric Power R&D http://www.fe.doe.gov/coal_power/fuelcells/fuelcells_seca.shtml


**Subtopic b: High-Temperature Net-Shape Insulation Material**


4. Larminie, J. and Dicks, A., *Fuel Cell Systems Explained*, West Sussex, England: John Wiley & Sons, Ltd., June 2000. (ISBN: 0-471-49026-1)

5. Nguyen, Q. M. and Takahashi, T., *Science and Technology of Ceramic Fuel Cells*, Amsterdam: Elsevier Science, 1995. (ISBN: 0-444-89568-X)

6. *Solid State Energy Conversion Alliance* U.S. DOE Electric Power R&D http://www.fe.doe.gov/coal_power/fuelcells/fuelcells_seca.shtml

7. Veyo, S. E., "Evaluation of Fuel Impurity Effects on Solid Oxide Fuel Cell Performance," Final Technical Report, 1998. (DOE Contract No. DE-AC21-89MC26355-02) (Available at: http://www.osti.gov/bridge/. Click on Advanced Search. Under "Field," select "Identifying Numbers." After "contains," key in "774909.")

**Subtopic c: Fabrication of Solid Oxide Fuel Cell Structures via Spray Deposition**


8. Larminie, J. and Dicks, A., *Fuel Cell Systems Explained*, West Sussex, England: John Wiley & Sons, Ltd., June 2000. (ISBN: 0-471-49026-1)

9. Nguyen, Q. M. and Takahashi, T., *Science and Technology of Ceramic Fuel Cells*, Amsterdam: Elsevier Science, 1995. (ISBN: 0-444-89568-X)

10. *Solid State Energy Conversion Alliance* U.S. DOE Electric Power R&D http://www.fe.doe.gov/coal_power/fuelcells/fuelcells_seca.shtml


## 30. GREENHOUSE GASES AND WATER RESOURCES

The environment is a major concern to the fossil energy program. As more and more emission issues become resolved, global warming and water resources have moved up in importance. Global warming is a consequence of the heat-retaining property of gases such as carbon dioxide ($CO_2$), released to the atmosphere from the combustion of fossil fuels for power generation and from the natural decomposition of organic carbons such as fibers, tissues, leaves, and food. Because $CO_2$ is a heat opaque gas, radiation does not simply pass through it; rather, through various modes of vibration, some of the heat in the radiation is absorbed by $CO_2$ molecules. Other gases such as methane ($CH_4$) and nitrous oxide ($N_2O$) share this partial heat-retaining property. Together, they are known as greenhouse gases. Power generation processes also have a negative impact on our water resources. Power plants, particularly coal plants, are heavily dependent on water for cooling, and mining for fuels also uses large amounts of water. The focus of this topic is on reducing both the level of greenhouses gases and the amount of water use associated with fossil energy processes. **Grant applications are sought only in the following subtopics:**

**a. Chemical Sequestration of $CO_2$**—The combination of high rates of $CO_2$ generation and the relatively slow rate of converting gaseous $CO_2$ to organic carbon or carbohydrates, $(CH_2O)_X$, by nature's photosynthesis process aggravates the greenhouse problem and calls for the development of synthetic processes to restore the balance. Faster $CO_2$ sequestration by chemical means at combustion sources with high $CO_2$ concentrations (i.e., stationary power plants) would be highly desirable. Inorganic chemical reactions would be rapid and easily implemented in large volumes. By taking advantage of the acidic nature of $CO_2$ in aqueous media, ammonia/water liquors can be used to scrub out the $CO_2$ in the form of ammonium bi-carbonates and carbonate, thereby "fixing" or retaining the carbon in $CO_2$ in a stable chemical compound:

$NH_3+H_2O+\ CO_2\ = NH_4HCO_3$, Ammonium bicarbonate

$2NH_3+2H_2O+CO_2\ = (NH_4)_4CO_3$, Ammonium carbonate

These salts of ammonia, often referred to as nitrogen fertilizers, serve as nutrients to support nature's photosynthesis process – as nutrients, they contribute to storing organic carbon in the soil, both in large quantities and for long duration. Ammonium bicarbonate (ABC) has been used overseas as an inexpensive nitrogen fertilizer since 1950. However, ABC is volatile and unstable, and incurs an appreciable amount of loss in storage. Although the additive-added ABC has shown much improvement, questions remain concerning the fate of the carbon elements in ABC. In particular, does a significant portion of the $HCO_3$ in the ABC percolate down into the ground water and become sequestered underground for the long term? Some of the carbon reverts back to $CO_2$ by ABC decomposition, and some converts to biomass $(CH_2O)_X$ inside the plant. Only a fraction of the carbon, in the form of bicarbonate, percolates down into the alkaline aquifer to subsequently become permanently neutralized as carbonate or other stable carbon compounds.

Grant applications are sought to develop a carbon material balance for a test bed, in order to determine the percentage of carbon in the ABC that is (1) lost to the atmosphere as $CO_2$; (2) converted to and harvested as biomass, $(CH_2O)_X$; and (3) percolated down to and sequestered in the ground water. This carbon material balance should be measured and analyzed free from the interference of atmospheric carbon dioxide. Tests should be conducted with at least three (3) representative soils, all of which would be likely future test soils. Selected soils should be in steady state (i.e., under typical cultivation or use) with respect to organic carbon content, so as to eliminate organic carbon content as a variable; at the end of each test, a representative soil sample should be analyzed to verify that the organic carbon content has not undergone significant change. Based on the carbon material balance, a mathematical strategy for conducting the carbon balance, and if possible, a means of assessing the concentration and duration of organic carbon compounds [mostly biomass, $(CH_2O)_X$] in a selected soil. Where organic carbon and its corresponding in-soil residence time would require measurement in selected soils, applicants should demonstrate that the analytic techniques developed and verified in this effort would serve as a useful reference guide. Finally, grant applications should describe (1) the nature of the apparatus and techniques used to obtain data; and (2) any assumptions concerning whether a net percolation of rain water to ground water is taking place and, if so, the likelihood of the ABC or the BC being carried down to and tied up by the ground water strata.

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

**c. Instrumentation Systems for Monitoring and Verifying Carbon-Sequestration**—New, low-cost methods for determining and verifying carbon sequestration are needed to lower the overall cost of carbon sequestration. Grant applications are sought for new reliable, low-cost instrumentation, diagnostic tools, and measurement systems that can be used to monitor and verify the sequestration of carbon in both terrestrial and geologic storage sites. For terrestrial sequestration, systems must be capable of covering a large geographical area and measuring net carbon uptake, after accounting for generation of methane ($CH_4$) and nitrous oxide ($N_2O$). For sequestration in geologic reservoirs, the systems must include methods to track flows within the reservoirs as well as migrations out of the reservoirs. gallons of water are required for each kWh of power produced from coal. Thermoelectric power production uses approximately 132,000 Mgal/day of fresh water, second only to irrigation. Mining also uses a large amount of water, estimated at 3,770 Mgal/day, impacting both surface and ground water. In power generation, the largest single use of water is for cooling the low-pressure steam from the turbine. Air has been considered as an alternative, but air-cooled systems (sometimes referred to as dry systems) can have associated capital-cost and energy-inefficiency penalties, particularly in retrofit applications. Grant applications are sought to develop novel concepts and technology to reduce both the amount of water used and the potential impact on water quality, and must be directed toward one following areas of interest: (1) reducing water used in power generation, (2) water quality improvements in power generation; and (3) reducing water usage and water-related environmental impacts associated with the mining of fossil fuel.

**References:**

**Subtopic a: Chemical Sequestration of $CO_2$**


1. Bai, H., and Yeh, A. C., "Removal of $CO_2$ Greenhouse Gas by Ammonia Scrubbing," *Industrial and Engineering Chemistry Research*, 36(6): 2490-2493, 1997. (ISSN: 0888-5885)

2. "$CO_2$AL [Coal]: Environmental Enemy No. 1," *The Economist*, July 6, 2002. (ISSN: 0013-0613)

3. Hatch, T. F., Jr., "Simultaneous Absorption of Carbon Dioxide and Ammonia in Water," *I & EC Fundamentals* 1(3): 209-214, August 1962. (ISSN: 0196-4313)


**Subtopic b: Non-Carbon Dioxide (Non-$CO_2$) Greenhouse Gas Reduction**


4. *Final Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions*, September 1999. (Report No. EPA430-R-99-013) (Available on the Web at: www.epa.gov/ghginfo/reports/index.htm. Scroll down to title.) (See also *Addendum to EPA 430-R-99-013: 2001 Update*, December 2001.

**Subtopic c. Low Temperature Sulfur Removal Technologies**


13. Larminie, J. and Dicks, A., *Fuel Cell Systems Explained*, West Sussex, England: John Wiley & Sons, Ltd., June 2000. (ISBN: 0-471-49026-1)

14. Nguyen, Q. M. and Takahashi, T., *Science and Technology of Ceramic Fuel Cells*, Amsterdam: Elsevier Science, 1995. (ISBN: 0-444-89568-X)

15. *Solid State Energy Conversion Alliance* U.S. DOE Electric Power R&D, http://www.fe.doe.gov/coal_power/fuelcells/fuelcells_seca.shtml

16. Takahashi A., et al., "New Sorbents for Desulfurization by Π-Complexation: Thiophene/Benzene Adsorption," *Industrial & Engineering Chemical Research*, 41:2487-2496, 2002. (ISSN: 0088-5885)


* Available from National Technical Information Service. See Solicitation General Information and Guidelines, section 7.1.

## 32. OIL AND FUEL TECHNOLOGIES

Much of the known oil reserves discovered in the United States cannot be recovered by conventional techniques. Therefore, the Department of Energy (DOE) seeks innovative methods and concepts that will contribute to more efficient and economic processes for the recovery and utilization of oil. In addition, the utilization of fossil fuels can be enhanced by the commercial production of chemical products from fossil fuel resources. Accordingly, the development of processes to convert these resources to commercial chemicals is an important goal. **Grant applications are sought only in the following subtopics:**

**a. Real-Time Fluid Identification During Drilling**—Drilling technology has progressed to the point that it is now possible for important physical and petrophysical data to be rapidly transmitted to the surface. This data allows rig operators to make quicker decisions with less "down time" caused by the wait for necessary information. However, two pieces of information that still elude decision-makers during the drilling process are the fluid pressure and fluid composition in the rock (identified the as a critical need by industry representatives – see report at the website www.npto.doe.gov). Although mud returns can be analyzed to determine if fluid is entering the hole, the time delay can be significant when drilling deep wells with balanced or overbalanced mud conditions. Even underbalanced drilling does not provide the information to the surface in real-time. Also, samples can be contaminated by uphole formations. Therefore, grant applications are sought to develop technology that can identify the fluid flow and composition at the bit during drilling, transmit the information in real-time, and survive the rugged downhole conditions. Such a capability would save time and money as well as add greater safety to the operations.

**b. Petroleum Fuels**—Gas Conversion Technologies (GCT), an integral component of DOE's Petroleum Fuels program, focuses on advancing technology needed to economically utilize natural gas resources in regions that are remote from their markets. The driving force for the GCT effort is to expand the transport and marketability of the vast gas resources of Alaska's North Slope (ANS). The GCT emphasis is on chemically changing the gas to a stable, ultra-clean-burning hydrocarbon liquid, fully compatible with modern vehicle fuels used to power our vast automobile and truck fleet. GCT using the Fischer-Tropsch (FT) process would be the technology of choice for ANS gas, but the combination of current FT economics and ANS's distant location and inhospitable climate poses difficult challenges to implementation. Grant applications are sought to develop innovative technology for one or more parts of the multi-step FT/GCT process, or for process integration, in order to demonstrate economic feasibility at the ANS and other prospective U.S. locations. Areas of research interest include: (1) reducing the first-step costs of syngas manufacture, (2) reducing costs associated with the subsequent syngas conversion to a liquid, and (3) upgrading the resulting liquid to needed fuel products.

**c. Preparation of Chemicals by Oxidation of Coal**—Current thinking about the molecular structure of coal suggest the possibility of breaking up the molecule to recover relatively valuable, commercial chemical products. Breaking the molecule's weaker bonds with oxygen is appealing, but since 1984, this subject has received little attention in the literature. Prior to that, there were reports of rather straightforward reactions, primarily with the oxidants "air/alkali," nitric acid, and $H_2O_2$. The first of these approaches proved discouraging because of the cost of alkali use and because its weak oxidizing power resulted in only crude humic acids. Results for the other two oxidants were reasonably

encouraging – yielding di- and tri- basic acids as well as other products. Between 1988 and 1990, a series of reports were published by a DOE-funded project for the conversion of coal into a synthetic diesel fuel by reaction with $HNO_3$. The proposed process proceeded smoothly, and resulting lab-scale diesel engine tests were satisfactory. To conduct these tests, the crude, acid-liquefied, water insoluble coal extract was taken up in methanol and filtered; the water insoluble elemental analysis (54% C, 36.3% O) suggested that the product was primarily a dibasic acid with six linking or methyl carbons. An appealing aspect of this approach is the opportunity for regenerating the nitric acid by collecting and reoxidizing its oxides. Grant applications are sought to continue the evolution of processes for the oxidation of coal to commercial chemicals, 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.

**References:**

**Subtopic a: Real-Time Fluid Identification During Drilling**


1. *PRIME (Public Resources Invested in Management and Extraction) Workshop: A Long-Term E&P Initiative; Houston, Texas, October 23, 2001*, DOE National Energy Technology Laboratory, 2002. (Available at: http://www.npto.doe.gov/Prime.pdf)


**Subtopic b: Petroleum Fuels**


2. Dry, M. E., "The Fischer-Tropsch Process. 1950-2000," *Catalysis Today*, 71(3-4): 227, January 2002. (ISSN: 0920-5861)

3. Iglesia, E., "Design, Synthesis and Use of Cobalt-Based Fischer-Tropsch Synthesis Catalysts,"*Applied Catalysis*, 161(1-2): 59-78, 1997. (ISSN: 0926-860X)


**Subtopic c: Preparation of Chemicals by Oxidation of Coal**


4. Bearse, A. E., et al., *Production of Chemicals by the Oxidation of Coal*, Columbus, OH: Battelle Memorial Institute, March 31, 1975. (Report No. NP-20455) (OSTI ID: 5114093)

5. Coca, J., "Production of a Nitrogenous Humic Fertilizer by the Oxidation-Ammoniation of Lignite," *Journal of Industrial and Engineering Chemistry, Product Research and Development*, 23(4) 620-624, 1984. (Full text available from American Chemical Society. Web site: http://www.acs.org/. Under "Choose a page" click on "ACS Publications," then on "Journals & Magazines," and then on journal title.)

6. Dyrkacz, G. R., *Chemical Feedstocks from Coal for High Performance Polymers*, Internal Argonne Laboratory Summary Report, prepared by Bonsignore Energy Systems under contract with Argonne National Laboratory, 1993. (Available from Ted Simpson. Telephone: 301-903-3913)

7. Mayo, F. R., et al., *Dissolving Coal at Moderate Temperatures and Pressures*, Final Report, Menlo Park, CA: SRI International, September 21, 1984. (Report No. DOE/PC/50788-T5) (NTIS Order No. DE85001790. Available by phone order only. See Solicitation General Information and Guidelines, section 7.1)

8. Schulz, J. G., et al., *Oxidative Derivatization and Solubilization of Coal*, May 1988. (Report No. DOE/PC/90006) (Avail at: http://www.osti.gov/bridge/. Under "Advanced Search," search by title in double quotes, and by author.)


## PROGRAM AREA OVERVIEW
## OFFICE OF FUSION ENERGY SCIENCES

http://wwwofe.er.doe.gov

The Department of Energy sponsors fusion science and technology research as a valuable investment in the clean energy future of this country and the world, as well as to sustain a field of scientific research - plasma physics - that is important in its own right and has produced insights and techniques applicable in other fields of science and industry. The mission of the Fusion Energy Sciences (FES) program is to acquire the knowledge base needed for an economically and

***Please note:*** *(1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

environmentally attractive fusion energy source. FES research efforts seek to: (1) understand the physics of plasmas, the fourth state of matter - plasmas constitute most of the visible universe, both stellar and interstellar, and progress in plasma physics has been the prime engine driving progress in fusion research; (2) identify and explore innovative and cost-effective development paths to fusion energy - the current fusion program encourages research on a wide range of approaches, including the tokamak, the leading power plant candidate, other magnetic configurations, and inertial fusion energy using particle beams or lasers; and (3) explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in a international effort - reducing costs, avoiding duplication of efforts, and bringing the best available scientific and engineering talent together to seek solutions to complex problems can best be done through the cooperative efforts of the world fusion community.

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

## 33. FUSION SCIENCE AND TECHNOLOGY

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

**a. Diagnostics for Magnetic and Inertial Fusion Plasma Research**—Grant applications are sought to develop measurement techniques for parameters such as plasma density, electron and ion temperature, plasma current and current density, plasma position and shape, impurity density, magnetic field strength, ambipolar potentials, and radiation from the plasma. Diagnostics suitable for experimental devices using relatively low magnetic fields or burning plasmas are of particular interest. New diagnostics for measurements in the 3-dimensional plasmas characteristic of stellarators are also needed. In addition, methods are desired for examining the edge and divertor regions in tokamak plasmas. Both new techniques and methods to improve the accuracy and resolution of existing diagnostics (e.g., improving the signal-to-noise ratio or extending the range of measured parameters) will be considered. Measurements must be both spatially and temporally resolved for both the absolute values of parameters and for small relative differences. For some of the above parameters, real-time measurements will be an advantage in order to provide for plasma control. For the DIII-D experimental program at General Atomics, diagnostics are needed for: (1) fluctuations of electron and ion temperatures, electron density and electric field, particularly in the high density plasma core (fluctuation frequencies are typically in the range of 100 KHz to several MHz, and fluctuation levels are typically less than 1% of the quasi-steady-state plasma levels); (2) transport due to fluctuations, which requires cross-correlations between density, temperature and velocity fluctuations; (3) visualization of turbulence in two dimensions, or even three dimensions; and (4) imaging of non-thermal electrons in two dimensions, with energy resolution if possible. For additional information, see the summary of the February 1998 workshop addressing measurement needs in magnetic fusion devices, listed as one of the references.

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

Grant applications are also sought to develop instrumentation and time-resolved measurement

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

**b. Components for the Generation, Transmission, and Launching of High Power Electromagnetic Waves**—Tools are needed to support fusion experimental research in such areas as plasma heating and temperature profile control. 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 (50 to 300 MHz), lower hybrid resonance heating (2 to 20 GHz), and electron cyclotron resonance heating (100 to 300 GHz). Components of interests include: power supplies, antenna and launching systems, tuning and matching systems, unidirectional couplers, mode convertors, windows, output couplers, loads, and diagnostics to evaluate the performance of these components, fault protection devices and energy extraction systems from spent electron beams.

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

Grant applications are also sought to develop software tools useful for the analysis and distribution of fusion data. Areas of interest include methods for coupling codes across architectures and through the Internet; techniques for making highly configurable scientific codes; data management and analysis techniques for large data sets; and remote collaboration tools that enhance the ability of a geographically distributed group of scientists to interact in real-time.

The computer algorithms and programming tools should be developed using modern software techniques and should be based on the best available models of plasma behavior.

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



***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**References:**


**Subtopic a: Diagnostics for Magnetic Fusion Plasma Research**

1. Helstrom, C. W., *Statistical Theory of Signal Detection*, New York: Pergamon Press, January 1968. (ISBN: 0080132650)

2. Hutchinson, I. H., *Principles of Plasma Diagnostics*, Cambridge, MA: Cambridge University Press, 1987. (ISBN: 0-521-326222-0)

3. Kosko, B., *Neural Networks for Signal Processing*, New York: Prentice Hall, 1992. (ISBN: 0-13-617390-X)

4. Luhmann, N. C. and Peebles, W. A., "Instrumentation of Magnetically Confined Fusion Plasma Diagnostics," *Review of Scientific Instruments*, 55(3): 279-331, March 1984. (ISSN: 0034-6748)

5. "Proceedings of the 12th International Symposium on Heavy Ion Inertial Fusion, Heidelberg, Germany, September 24-27, 1997," *Nuclear Instruments & Methods in Physics Research*, Section A, 415(1, 2), 1998. (ISSN: 0168-9002) (Special Issue)

6. *Report on the Workshop on Measurement Needs in Magnetic Fusion Plasmas, Germantown, MD, February 25, 1998.* (Available on the Web at: http://wwwofe.er.doe.gov/More_HTML/pdffiles/diag.pdf)

7. Simpson, P. K., *Artificial Neural Systems: Foundations, Paradigms, Applications and Implementations*, New York: Pergamon Press, February 1990. (Hardcover ISBN: 0080378951; Paperback ISBN: 0080378943)

8. Stott, P. E., ed., *Diagnostics for Experimental Thermonuclear Fusion Reactors: Proceedings of the International Workshop of Diagnostics for ITER, Varenna, Italy, Aug. 28-Sept. 1, 1995*, New York: Plenum Press, 1996. (ISBN: 0-306-45297-9)

**Subtopic b: Components for the Generation, Transmission, and Launching of High Power Electromagnetic Waves**

9. Bernabei, S. and Paoletti, F., eds, *13th Topical Conference on Radio Frequency Power in Plasmas, Annapolis, MD, April 1999*, New York: American Institute of Physics, December 1999. (AIP Conference Proceedings No. 485) (ISBN: 1563968614)(Available from Springer-Verlag New York, Inc. Telephone: 800-809-2247. Website: http://www.springer-ny.com)

10. Liu, Shenggang and Shen, Xuechu, eds., *2000 25th International Conference on Infrared and Millimeter Waves Conference Digest*, IEEE Press, 2000. (ISBN: 0-7803-6513-5)

**Subtopic c: Plasma Simulation and Data Analysis**

11. Blum, J., *Numerical Simulation and Optimal Control in Plasma Physics; with Applications to Tokamaks*, New York: Wiley, 1989. (Gauthier-Villars Series in Modern Applied Mathematics) (ISBN: 0471921874)

12. Dawson, J. M., et al., "High Performance Computing and Plasma Physics," *Physics Today*, 46(3): 64-70, March 1993. (ISSN: 0031-9228)

13. Orfali, R. and Harkey, D., *Client/Server Programming with JAVA and CORBA*, 2nd ed., John Wiley and Sons, March 1998. (ISBN: 0-471-24578-X) (Available from publisher at: http://www.wiley.com/cda/product/0,,047124578X,00.html)

**Subtopic d: Superconducting Magnets and Materials**

14. Iwasa, Y., *Case Studies in Superconducting Magnets: Design and Operational Issues*, New York: Plenum Press, 1994. (ISBN: 0-306-44881-5)

15. Wilson, M. N., *Superconducting Magnets*, Chilton, England: Clarendon Press Oxford, 1983. (Monographs on Cryogenics)(ISBN: 0-19-854805-2)


## 34. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUTURE FUSION ENERGY SYSTEMS

An attractive fusion energy source will require the development of technologies and materials that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to

achieve safe, reliable, economic, and environmentally benign operation of fusion energy systems. **Grant applications are sought only in the following subtopics:**

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

Grant applications also are sought to develop: (1) innovative new modeling tools ranging from atomistic and molecular dynamics simulations of atomic collision and defect migration events (including solute binding effects) to improved finite element analysis (mechanical deformation and fracture) or thermodynamic stability (materials by design) tools; and (2) innovative methods or experimental apparatuses that would enhance the ability to obtain key mechanical or physical property data on miniaturized specimens – of particular interest is the micromechanics evaluation of deformation and fracture processes.

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

**b. Particle and Heat Removal with Liquid Surfaces**—Innovative liquid surface concepts are desired for heat removal from surface heat fluxes at first walls and divertors of about 2 $MW/m^2$ and 50 $MW/m^2$, respectively, with good safety, reliability, and maintenance features. Current interests are focused on evaluating the use of flowing liquids with direct exposure to the plasma that can potentially remove particles as well as surface heat. Candidate liquids metals include lithium, tin-lithium, tin, gallium, and lead-lithium. Other candidate liquids are lithium bearing salts, such as $BeF_2$-LiF and $BeF_2$-LiF-NaF. Grant applications are sought to develop: (1) techniques for the removal of first wall and divertor heat loads by free surface flowing liquids (proposed techniques should address the effect of magnetohydrodynamics on heat transfer and should also consider heat removal enhancement techniques, such as turbulence promoters); (2) efficient nonlinear solution methods, as well as alternate object-oriented languages for computational tools, to model fusion-relevant issues of liquid wall flows, such as heat transfer at free surfaces and free flows with magnetohydrodynamic effects and turbulence; (3) techniques, such as the addition of alloying materials, to improve the compatibility of candidate liquids with either the plasma operation (e.g. lowering vapor pressure) or with structural/insulator materials (e.g. ceramic insulators that can be wetted by Li); (4) nozzles for liquid injection (e.g., streams, jets, films, and droplets) and collection/removal techniques that are drip and splash free, self-cooling, and efficient in head recovery at the outlet; (5) non-invasive diagnostics for experiments to study high temperature free surface liquid flows in magnetic fields (such diagnostics might include measurements of mean flow velocity, turbulence intensity, velocity fluctuations, flow depth, and surface/depth temperature profiles); (6) efficient techniques for pumping liquid metals in the presence of a magnetic field, including the production of free surface flows; and (7) techniques for validation of fluid flow and heat transfer models.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**References:**

**Subtopic a: Structural Materials and Coatings**


1. Bloom, E. E., "The Challenge of Developing Structural Materials for Fusion Power Systems," *Journal of Nuclear Materials*, 258-263:7-17, 1998. (ISSN: 0022-3115)

2. Bloom, E. E., et al., *Advanced Materials Program*, (Appendix C to the Virtual Laboratory for Technology Roadmap document: Baker, C. C., *The U.S. Technology Program*), January 1998. (Available on the Web at: http://www.ms.ornl.gov/programs/fusionmatls/planning.htm. Select *Advanced Materials Program...*)

3. Ehrlich, K., et al., "International Strategy for Fusion Materials Development," *Journal of Nuclear Materials*, 283-287:79-88, 2000. (ISSN: 0022-3115)

4. Fusion Materials Science Program U.S. DOE Office of Fusion Energy Sciences http://www.fusionmaterials.pnl.gov/

5. *Proceedings of the 9th International Conference on Fusion Reactor Materials (ICFRM-9), Colorado Springs, CO, October 1999*, Journal of Nuclear Materials, Vols. 283-287, 2000. (ISSN: 0022-3115)

6. Smith, D. L., et al., "Materials Integration Issues for High-Performance Fusion Power Systems," *Journal of Nuclear Materials*, 258-263(Part 1): 65-73, October 1998. (ISSN: 0022-3115)

7. Stoller, R.E., et al., *A Whitepaper Proposing an Integrated Program of Theoretical, Experimental, and Database Research for the Development of Advanced Fusion Materials*, U.S. Department of Energy, November 1999 (Full text available on the Web at: http://www.ms.ornl.gov/programs/fusionmatls/pdf/modeling-whitepaper-final.pdf)

8. U.S. Fusion Materials Sciences Semiannual Progress Reports, U.S. DOE Oak Ridge National Laboratory http://www.ms.ornl.gov/programs/fusionmatls/pubs/semiannual.htm

9. Zinkle, S. J. and Ghoniem, N. M., "Operating Temperature Windows for Fusion Reactor Structural Materials," *Fusion Engineering and Design*, 49-50:709-717, 2000. (ISSN: 0920-3796)


**Subtopic b: Particle and Heat Removal with Liquid Surfaces**


10. Abdou, M. A., et al., eds., *Proceedings of the 3rd International Symposium on Fusion Nuclear Technology, Los Angeles, CA, June 4-6, 1994*, Fusion Engineering and Design, 27-29(parts A-C), March 1995. (ISSN: 0920-3796)

11. Abdou, M. and the APEX Team, "Exploring Novel High Power Density Concepts for Attractive Fusion Systems," *Fusion Engineering and Design*, 45:145-167, 1999. (ISSN: 0920-3796)

12. Advanced Limiter-Divertor Plasma-Facing Surfaces (ALPS), *U.S. DOE Argonne National Laboratory* http://starfire.ne.uiuc.edu/DOEALPS.html

13. *Advanced Power EXtraction (APEX) Study* University of California, Los Angeles http://www.fusion.ucla.edu/APEX/

14. Bastasz, R. and Eckstein, W., "Plasma-Surface Interactions on Liquids," *Journal of Nuclear Materials*, Vols.290-293: 19-24, 2001. (ISSN: 0022-3115)

15. Mattas, R. F., et al., "ALPS - Advanced Limiter-Divertor-Plasma-Facing Systems", *Fusion Engineering and Design*, 49:127-134, 2000 (ISSN: 0920-3796)


## 35. INERTIAL FUSION ENERGY

Inertial fusion energy is produced by ignition and burn of an energy-producing target. Conditions necessary for ignition and burn result from the external application of energy to the fuel target by an external driver. Although several drivers such as lasers and ion beams have been considered, the emphasis in the fusion energy science program is on intense heavy ion beams as drivers. These beams are produced by induction linear accelerators with components to produce, accelerate, transport, and focus beams of required energy and intensity. The Fusion Energy Sciences program in inertial fusion energy supports research and technology in the generation, transport, and measurement of these heavy ion beams. There is also interest in selected technology topics with relevance to different inertial fusion energy driver concepts. **Grant applications are sought only in the following subtopics:**

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

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

**c. Technology for Inertial Fusion Energy (IFE)**—In an inertial fusion power plant, targets must be repetitively injected into a reactor chamber and driven by either a heavy ion beam, a high power laser, or a pulsed power machine (z-pinch or magnetized target fusion). The targets must be fabricated and injected with great precision. Moreover, the target releases a high intensity burst of neutrons, energetic particles, and x-rays that must be contained within the chamber. Grant applications are sought to develop:

(1) Damage resistant chamber materials. The x-rays, neutrons, and particle debris released in inertial fusion have energies up to several $MJ/m^2$ and are emitted on a time scale from 1 ns to 100 microseconds. Wall materials must survive this environment for periods of up to several years at repetition rates up to 10 Hz. The wall materials must provide low radioactivity under neutron exposure and high temperature operation consistent with efficient power production. Innovative materials, which can withstand this environment, are sought. Schemes that can protect or shield the first wall are also of interest. In addition, innovative low-cost approaches to testing pulsed damage resistance of chamber materials are needed.

(2) Damage resistant laser optics and optics protection methods for the last optical element before the reactor chamber in a laser fusion system. Both metal mirrors and fused silica windows have been proposed for this "final optic," but other technologies may be appropriate. The final optic must operate at 1/4 to 1/3 micron wavelength and must be protected from exposure or capable of withstanding pulsed irradiation by neutrons, x-rays, and debris. In either approach, the optical elements must survive for several years.

(3) Low-cost fabrication methods for mass-produced inertial fusion energy targets, including targets filled with deuterium-tritium fuel and coated with a protective layer. In an IFE power plant, about 500,000 cryogenic targets must be prepared and injected each day at a rate of 5-10 Hz into a target chamber operating at elevated temperatures. These targets must be precisely made and cost less than $0.30 each.

(4) Methods for target injection and tracking. Targets driven by heavy ion or laser beams must be injected into the chamber at a rate of 5-10 Hz, at velocities from 200 to 400 m/s, and with an acceleration approaching 1000 g. The targets also must be tracked precisely inside the chamber. Gas guns, electrostatic accelerators, and electromagnetic accelerators are being evaluated as candidate target injectors. Techniques to accurately track the target (in order to steer them or the driver beams) also are needed.

(5) Design, construction, testing, and efficient procedures for the repetitive replacement of recyclable transmission line (RTL), target assembly, and close-packed coolant. For pulsed-power drivers (z-pinch and magnetized target fusion), the RTL, target assembly, and close-packed coolant (for shock mitigation) must be repetitively replaced on a relatively slow time scale (about 0.1 Hz).

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**References:**

**Subtopic a: Beam Generation and Transport, and Subtopic b: Models for Electron Production in Accelerators for Heavy-Ion Beam-Driven Fusion**


1. Caparaso, G. J. "Progress in Induction LINACs," *Proceedings of the XX International Linac Conference, (Linac 2000), Monterey, CA, August 21-25, 2000*, Stanford Linear Accelerator Center, September 2000. (Full *Linac 2000* proceedings available at: http://www.slac.stanford.edu/econf/C000821. For Caparaso paper, select "Author List" on menu at left, scroll down to Caparaso, and select "WE101.")

2. Cook, E. G. "Review of Solid State Modulators," *Proceedings of the XX International Linac Conference, (Linac 2000), Monterey, CA, August 21-25, 2000*, Stanford Linear Accelerator Center, September 2000. (Full *Linac 2000* proceedings available at: http://www.slac.stanford.edu/econf/C000821. For Cook paper, select "Author List" on menu at left, scroll down to Cook, and select "WE103.")

3. Grote, D. P., et al., "New Methods in WARP," *Proceedings of the International Computational Accelerator Physics Conference, Monterey, CA, September 14-18, 1998*, American Institute of Physics, 1998. (Full text of paper available at: http://www.slac.stanford.edu/xorg/icap98/papers/C-Tu08.pdf)

4. Molvik, A. W. and Faltens, A., "Induction Core Alloys for Heavy-Ion Fusion-Energy Accelerators," *Physical Review Special Topics - Accelerators and Beams*, Vol. 5, Article 080401, August 5, 2002. (Full text available from American Physical Society at: http://prst-ab.aps.org/)

5. *Proceedings of the 12th International Symposium on Heavy Ion Inertial Fusion, Heidelberg, Germany, September 24-27, 1997*, Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 415(1, 2), 1998. (ISSN: 0168-9002) (Special Issue) (Titles and abstracts of symposium documents available on the Web at: http://www.sciencedirect.com/science/publications/journal/physics)

6. *Proceedings of the 13th International Symposium on Heavy Ion Inertial Fusion, San Diego, CA, March 13-17, 2000*, Nuclear Instruments & Methods in Physics Research, Section A, 464(1-3), 2001. (ISSN: 0168-9002) (Titles and abstracts of symposium documents available on the Web at: http://www.sciencedirect.com/science/publications/journal/physics)

7. *Sabbi, G. L., et al., "Development of Superconducting Quadrupoles for Heavy Ion Fusion,"* Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, June 18-22, 2001, *New York: APS/IEEE, 2001. (ISBN: 0-7803-7193-3) (IEEE Order No.01CH37268C) (Full proceedings available on the Web at: http://pac2001.aps.anl.gov/. Select "Conference Proceedings," and search under "Author Index.")*


**Subtopic c. Technology for Inertial Fusion Energy**


8. Bodner, S. E., et al., "High-Gain Direct-Drive Target Design for Laser Fusion," *Physics of Plasmas*, 7(6): 2298-2301, June 2000. (ISSN: 1070-664X)

9. Callahan-Miller, D. A. and Tabak, M., "A Distributed Radiator Heavy Ion Target Driven by Gaussian Beams in a Multibeam Illumination Geometry," *Nuclear Fusion*, 39(7): 883-892, July 1999. (ISSN: 0029-5515)

10. Goodin, D. T., et al., "Developing Target Injection and Tracking for Inertial Fusion Energy Power Plants," *Nuclear Fusion*, 41(5): 527, May 2001. (ISSN 0029-5515)

11. Goodin, D. T., et al., "Developing the Basis for Target Injection and Tracking in Inertial Fusion Energy Power Plants," *Fusion Engineering and Design*, 60:26-36, 2002. (ISSN: 0920-3796)

12. Goodin, D.T., et al., "Progress Towards Demonstrating IFE Target Fabrication and Injection," *Proceedings of the Second International Conference on Inertial Fusion Sciences and Applications: IFSA 2001, Kyoto, Japan, September 9-14, 2001*, p. 746, Paris: Elsevier, 2002. (ISBN: 2-84299-407-8) (ISSN: 1622-9878)

13. Latkowski, J. F., et al., "Preliminary Safety Assessment for an IFE Target Fabrication Facility," *Fusion Technology*, 39(2,2): 960, March 2001 (ISSN: 0748-1896)


***Please note:* (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.**

14. Marshall, C. D., et al., "Induced Optical Absorption in Gamma, Neutron and Ultraviolet Irradiated Fused Quartz and Silica," *Journal of Non-Crystalline Solids*, 212(1): 59-73, May 1997. (ISSN: 0022-3093)

15. Meier, W. R., et al., "Issues and Opportunities for IFE Based on Fast Ignition", *Proceedings of the Second International Conference on Inertial Fusion Sciences and Applications: IFSA 2001, Kyoto, Japan, September 9-14, 2001*, p. 689, Paris: Elsevier, 2002. (ISBN: 2-84299-407-8) (ISSN: 1622-9878)

16. Najmabadi, F., et al., "Assessment of Chamber Concepts for Inertial Fusion Energy Fusion Power Plants - The ARIES-IFE Study", *Proceedings of the Second International Conference on Inertial Fusion Sciences and Applications: IFSA 2001, Kyoto, Japan, September 9-14, 2001*, p. 701, Paris: Elsevier, 2002. (ISBN: 2-84299-407-8) (ISSN: 1622-9878)

17. Olson, C. L., et al., "Rep-Rated Z-Pinch Power Plant Concept," *ICC 2000: Innovative Confinement Concepts Workshop, Berkeley, California, February 22-25, 2000.* (Available on the Web at: http://icc2000.lbl.gov/. Select "Proceedings" on menu at left. Scroll down to "Advanced Boundary Concepts" section and select title.)

18. Petzoldt, R. W., et al., "Design of an Inertial Fusion Energy Target Tracking and Position Prediction System," *Fusion Technology*, 39(2,2): 678, March 2001. (ISSN: 0748-1896)

19. Schultz, K. R., "Cost-Effective Steps to Fusion Power: IFE Target Fabrication, Injection and Tracking," *Journal of Fusion Energy*, 17(3), September 1998. (ISSN: 0164-0313)

20. Schultz, K. R., et al., "Status of Inertial Fusion Target Fabrication in the U.S.A.," *Fusion Engineering and Design*, 44:441-448, February 1999. (ISSN: 0920-3796)

21. Tillack, M. S., et al., "ARIES Inertial Fusion Chamber Assessment," *Fusion Technology*, 39(2,2): 343, March 2001. (ISSN: 0748-1896)

## PROGRAM OVERVIEW - NUCLEAR PHYSICS

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

Nuclear physics research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which in turn determine the essential physical characteristics of the universe. The primary mission of the Nuclear Physics program is to develop and support the scientists, techniques, and facilities that are needed for basic nuclear physics research. Attendant upon this core mission are responsibilities to enlarge and diversify the nation's pool of technically trained talent and to facilitate transfer of technology and knowledge to support the nation's economic base.

Nuclear physics research is carried out at national accelerator facilities and through university programs. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator at MIT allow detailed studies of how quarks and gluons bind together to make protons and neutrons. CEBAF is planning a future upgrade in which the electron beam energy is doubled from 6 to 12 GeV. The Relativistic Heavy Ion Collider (RHIC), now in operation at Brookhaven National Laboratory (BNL), will instantaneously form submicroscopic specimens of quark-gluon plasma by colliding gold nuclei, thus allowing a study of the primordial soup of quarks and gluons thought to make up the early universe. RHIC is planning a beam luminosity upgrade in the future; a new electron-ion collider is also being discussed. The nuclear physics program supports research and facility operations that are directed towards understanding the properties of nuclei at their limits of stability and of the fundamental properties of nucleons and neutrinos. This research is made possible with the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) and the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL), which provide complementary facilities for stable and radioactive beams as well as a variety of species and energies. In addition, the operations of accelerators for in-house research programs at four universities (Yale University, Washington University, Texas A&M University, and Triangle Universities Nuclear Laboratory (TUNL) at Duke University) provide unique instrumentation with a special emphasis on training of students. The nuclear physics

program also supports non-accelerator experiments such as the Sudbury Neutrino Observatory (SNO) facility, constructed by a collaboration of Canadian, English, and U.S. supported scientists, now taking data on solar neutrino fluxes and providing the first results on the "appearance" of oscillations of electron neutrinos into another neutrino type. A proposed Rare Isotope Accelerator (RIA) facility is being designed that would provide a way to explore the limits of nuclear existence. By producing and studying highly unstable nuclei that are now formed only in the stars, scientists could better understand stellar evolution and the origin of the elements.

Our ability to continue making a scientific impact to the general community relies heavily on the availability of cutting edge technology and advances in detector instrumentation, electronics, software, and accelerator design. The technical topics which follow describe research and development opportunities in the equipment, techniques, and facilities that are needed to conduct and advance nuclear physics research at existing and future facilities.

## 36. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

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

**a. Materials and Components for Radio Frequency Devices**—Grant applications are sought for research and development leading to improved or advanced superconducting and room temperature materials or components for radio frequency (rf) devices used in particle accelerators. Areas of interest include: (1) peripheral components such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, and magnetostrictive cavity tuning mechanisms; (2) termination materials for use at 2 to 4 K, compatible with the ultra high vacuum and dust-free environment, and capable of absorbing microwaves efficiently from 2 to 90 Ghz; (3) methods to avoid inclusions in the superconducting material and contamination on the surface of the superconductor; (4) innovative designs for hermetically sealed refrigerators and other cryogenic equipment that simplify procedures and reduce costs associated with reparability and modification; (5) development of simple, low-cost mechanical damping techniques, effective in the 10-300 Hz range at 2 Kelvin, to reduce both construction and operating costs of facilities through smaller systems; and (6) designs of ultra-high vacuum pumps that can significantly reduce the partial pressure of helium.

Grant applications are also sought for the initial design, modeling, and development of a new 13 kW continuous wave klystron power source at 1497 MHz to drive accelerator superconducting cavities. The klystrons should be able to operate at a variety of power levels depending on the parameters of each superconducting cavity and on the energy delivered to the electron beams. Because each superconducting cavity may require a different power level of operation, the klystron should contain a perveance-determining electrode in the klystron gun to limit beam power dissipation when operating at less than full power. Also, because the klystrons will be part of an energy feedback system, they should operate about 10% below their saturated power levels to allow headroom for control by the feedback system; this situation requires good stability in the linear gain region of the klystron. Klystron power efficiency is of major importance in all these modes of operation. Permanent magnet focusing of this new klystron design is desirable, but electro-magnet focusing would also be acceptable if better rf stability and operating efficiency obtains. Efficiencies greater than 55% are desirable for rf to beam power.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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

Grant applications are also sought to develop concepts and designs to improve the stability and performance of high efficiency, high brightness, electron linear accelerator systems. Areas of interest include energy recovery systems that preserve beam quality by thoroughly treating higher order modes and beam break-up phenomena, electron cooling and optical-stochastic cooling for high-energy ion beams (e.g., RHIC luminosity upgrade) and electron-ion collisions (e.g. proposed electron collider with RHIC (eRHIC) or dedicated Electron Light Ion Collider at TJNAF), and increasing the threshold of multi-bunch, multi-pass beam breakup in energy-recovering electron linear accelerators. Grant applications must address not only beam dynamics but also the engineering issues of such systems by developing system and component level engineering requirements (particularly methods of handling the high power higher order nodes) and associated conceptual designs.

The dynamic control of the RF systems for high-gradient superconducting cavities is increasingly complex because detuning from the high electric fields can exceed the cavity bandwidth. The controls also must address microphonic vibrations, either by controlling the cavity frequency using active elements or by using a smart control algorithm. Therefore, grant applications are sought for concept development, system design, and prototype component development for the control of microphonic vibrations.

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

**c. Particle Beam Sources and Techniques**—Grant applications are sought to develop: (1) particle beam ion sources with improved intensity, emittance, and range of species (areas of interest include high-charge-state sources for heavy ions, sources for negative and light ions, and polarized sources for hydrogen ions and electrons); (2) ion sources for radioactive beams (emphasizing high efficiency, high-charge-state ions, high temperature operation for coupling to high temperature production targets, and element selectivity; e.g., through the use of laser ionization); (3) high brightness electron beam sources utilizing continuous wave superconducting rf cavities with integral photocathodes operating at high acceleration gradients; (4) high brightness electron beam sources utilizing continuous wave normal-conducting rf cavities with interchangeable photocathodes operating at high acceleration gradients; (5) power supplies to drive these sources; (6) techniques for secondary radioactive beam collection, charge equilibration, and cooling; (7) methods to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers or special stripping techniques); (8) high quantum efficiency, long life photocathodes for use with the high brightness electron sources; and (9) methods to improve high voltage stand-off and reduce field emission from high voltage electrodes in the presence of work function lowering material (i.e., cesium) in order to enhance the performance of photoemission electron sources.

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

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

**d. Accelerator Control and Diagnostics**—Grant applications are sought for: (1) "intelligent" software and hardware to facilitate the improved control and optimization of charged particle accelerators and associated components for nuclear physics research (developments that offer generic solutions to problems in the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning are especially encouraged); (2) advanced beam diagnostics concepts and devices that provide high speed computer-compatible measurement and monitoring of particle beam intensity, position, emittance, polarization, luminosity, momentum profile, time of arrival, energy, and helicity-correlated effects (including such advanced methods as neural networks or expert systems and techniques that are nondestructive to the beams being monitored) – these diagnostics should be able to handle the full range of beam power needed, from watts to megawatts; (3) beam diagnostic devices with increased sensitivities through the use of superconducting components, such as filters based on high $T_c$ superconducting technology or Superconducting Quantum Interference Devices; (4) measurements of direct current, charged particle, average beam currents in the range 0.1 to 100 μA with very high precision ($<10^{-4}$); (5) low current beam diagnostics for radioactive ion beams (for exotic nuclei that will only be available as beams with intensities less than $10^7$ nuclei/second (with such low beam intensities, it is very difficult to use standard beam diagnostic methods); and (6) high current, non-destructive beam diagnostics for high current electron beams, usable with 100 mA class electron beams such as may be available in energy recovery electron linacs used for electron cooling of ion beams or for electron-ion colliders.

**References:**


1. Bromley, D. A., ed., "Introduction: Evolution and Use of Nuclear Detectors and Systems," *Nuclear Instruments and Methods in Physics Research*, 162(1-3, pt.1): 1-8, June 1, 1979. (ISSN: 0029-554X) (This is a special issue entitled *Detectors in Nuclear Science*.)

2. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry, Proceedings of the Fourteenth International Conference Denton, TX, November 6-9, 1996*, New York: American Institute of Physics, 1997. (ISBN: 1-56396-652-2) (AIP Conference Proceedings No. 392)*

3. Duggan, J. L. and Morgan, I. L., eds., *Nuclear Instruments and Methods in Physics Research, Section B, Beam Interactions with Materials and Atoms*, 99(1-4), May 1995. (ISSN: 0168-583X)

4. *eRHIC, An electron beam for eA and polarized ep physics at RHIC* http://quark.phy.bnl.gov/~raju/eRHIC.html

5. Facco, A., et al., "Mechanical Stabilization of Superconducting Quarter Wave Resonators," *Proceedings of the 1997 17th Particle Accelerator Conference, PAC-97 Vancouver, BC, Canada, May 12-16, 1997*, 3:3084-3086, IEEE, 1998. (ISBN: 0-7803-4376-X)

6. Grunder, H. A., "CEBAF - Commissioning and Future Plans," *Proceedings of the 1995 Particle Accelerator Conference, Dallas, TX, May 1-5, 1995*, New York: IEEE, 1995. (ISBN: 0-7803-2934-1) (IEEE Catalog No. CH35843)

7. Harrison, M., "The RHIC Project - Status and Plans," *Proceedings of the 1995 Particle Accelerator Conference, Dallas, TX, May 1-5, 1995*, 1:401-405, New York: IEEE, 1995. (ISBN: 0780329341) (IEEE Catalogue No. 95CH35843) (Also available in book form: Grupen, C., ed., *Monographs on Particle Physics, Nuclear Physics & Cosmology*, no. 5, Cambridge University Press, July 1996. ISBN: 0521552168)

8. Hill, C. and Vretenar, M., *Proceedings of the 18th International Linac Conference, Geneva, Switzerland, August 26-30, 1996*, 2 vols., Geneva, Switzerland: CERN, 1996. (ISBN: 92-9083-093-X) (CERN Publ. 96-07) (Full text of proceedings available at: http://linac96.web.cern.ch/Linac96/Proceedings/

9. Kraimer, M., et al., "Experience with EPICS in a Wide Variety of Applications," *Proceedings of the 1997 Particle Accelerator Conference, Vancouver BC, Canada, May 12-16, 1997*, 2:2403-2409, IEEE 1998. (ISBN: 078034376X)

10. Litvinenko, V. N., et al., "Gamma- Ray Production in a Storage Ring Free-Electron Laser," *Physical Review Letters*, 78(24): 4569-4572, June 16, 1997 (ISSN: 0031-9007)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic: (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

11. Ludlam, T. W. and Stevens, A. J., *A Brief Description of the Relativistic Heavy Ion Collider Facility*, Brookhaven National Laboratory, June 1993. (Report No. BNL-49177) (NTIS Order No. DE93040311. See Solicitation Information and Guidelines, section 7.1.)

12. *Proceedings of the 1999 Particle Accelerator Conference, New York, New York, Mar. 29th-Apr. 2nd, 1999*, IEEE, 1998. (IEEE Catalog No. 99CH36366)

13. *Review of Scientific Instruments,* 71(2): 603-1239 February 2000. (ISSN: 0034-6748)

14. *Review of Scientific Instruments*, 63(4): 2125-2910, April 1992. (ISSN: 00346748)

15. *Review of Scientific Instruments*, 67(3, Part 2): 878-1683, 1996. (ISSN: 0034-6748)

16. *Scientific Opportunities with an Advanced ISOL Facility*, November 1997. (URL: http://www.phy.anl.gov/ria/index.html. Scroll down right-hand side of page, and select title to access 86-page pdf file.)

17. Stephenson, E. J. and Vigdor, S. E., eds., *Polarization Phenomena in Nuclear Physics: Eighth International Symposium, Bloomington, IN, September 1994*, Woodbury, NY: American Institute of Physics, September 1995. (ISBN: 1563964821) (AIP Conference Proceedings No. 339) (ISSN: 0094-243X)*

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

## 37. NUCLEAR PHYSICS DETECTORS, INSTRUMENTATION, AND TECHNIQUES

The Department of Energy (DOE) is interested in supporting projects that may lead to advances in target and detection systems for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art and outside the usual scope of research and development activities at the nuclear physics national accelerator facilities and university programs. In addition, a new suite of next-generation detectors will be needed for the proposed Rare Isotope Accelerator, the energy upgrade at TJNAF, the luminosity upgrade at RHIC, and the electron-ion accelerator. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

**a. Advances in Detector Technology**—Nuclear physics research has a need for devices for detecting, analyzing or tracking charged particles, neutrons, photons, and single atoms. These devices include: solid-state devices such as highly segmented coaxial and planar germanium detectors, silicon strip and silicon drift detectors; photosensitive devices such as avalanche photodiodes, hybrid photomultiplier devices, single and multi anode photomultiplier tubes, and other novel photon detectors; detectors utilizing photocathodes for Cherenkov and UV light detection, and the development of new types of large area photoemissive materials such as solid, liquid, or gas photocathodes; micro-channel plates; gas-filled detectors such as proportional, drift, streamer, Cherenkov, micro-strip, gas electron multiplier detectors, resistive plate chambers, and straw drift tube chambers; liquid argon and xenon ionization chambers; single-atom detectors using laser techniques and electromagnetic traps; particle polarization detectors; bolometers which can detect particles with high resolution; and electromagnetic and hadronic calorimeters. Grant applications are sought to develop advancements in detector technology for all of the above mentioned detectors.

With respect to solid state tracking devices, particularly segmented germanium and silicon drift, strip, and pixel detectors, grant applications are sought for: (1) manufacturing techniques, including interconnection technologies, for high granularity, high resolution, light-weight, and radiation-hard solid state devices; (2) highly arrayed solid state detectors for neutron detection, with integrated electronics to read-out pulse height. (for example, silicon strip or pixel arrays with integrated electronics and coating could be developed so that an alpha-particle is produced when hit with a thermal or cold neutron – the alpha-particle would recoil into the silicon for measurement resulting in an inexpensive, large acceptance, high rate device); (3) thicker (more than 1.5 mm) segmented silicon charged particle and x-ray detectors and associated high density, high resolution electronics; and (4) cost-effective production of n-type and p-type silicon drift chambers with active areas greater than 16 $cm^2$.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

With respect to position sensitive charged particle and photon tracking devices, grant applications are sought to develop: (1) highly efficient, position sensitive, high resolution, germanium gamma-ray detectors utilizing efficient pulse shape analysis schemes (capable of determining the exact position to within a few millimeters as well as the energy of individual interactions of gamma-rays with energies up to several MeV in germanium detectors, 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 in general, and for gamma-ray tracking in particular; (3) alternative materials, with the same or comparable resolution as 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 – this would allow for new detector applications in nuclear physics, medical imaging, etc.); (4) new contact technologies for germanium detectors, specifically to remove lithium contacts, which would allow enhanced segmentation and stability; (5) advances in more conventional charged particle tracking detector systems, such as drift chambers, pad chambers, time expansion chambers, and time proportional chambers (areas of interest include improved gases or gas additives – that resist aging, improve detector resolution, decrease flammability, and offer larger/more uniform drift velocity – for these chambers, and the development of innovative trackers for RHIC and CEBAF physics such as a fiber optic tracking devices).

With respect to particle identification detectors, grant applications are sought for: (1) inexpensive, large-area, high-quality Cherenkov materials; (2) inexpensive, position sensitive large-sized photon detection devices for Cherenkov counters; (3) affordable methods for the large volume production of xenon and krypton gas (which would contribute to the development of transition radiation detectors and would also have many applications in X-ray detectors); and (4) very high resolution particle detectors or bolometers based on semiconductor materials and cryogenic techniques. Of particular interest are detector technologies capable of measuring energies of alpha particles and protons with less than 5 keV resolution. This would allow spectroscopy experiments using light charged particles to be performed in the same way as gamma spectroscopy, enabling a deeper understanding of nuclear excitations not currently possible with gamma-ray spectroscopy.

**b. Scintillators and Associated Materials**—Grant applications are sought to develop new materials or advancements for: (1) scintillator materials for high resolution X-ray detectors (CdZeTe, $HgI_2$, AlSb, etc.); (2) plastic scintillators, fibers, and wavelength shifters; (3) cryogenic liquid scintillation gamma ray detectors (LXe); (4) Cherenkov radiator materials with indices of refraction up to 1.10 or greater with good optical transparency; and (5) stable calorimeter materials in single block lengths (up to 20 radiation lengths) which could be produced in large quantities and at low cost; and (6) composite materials with high radiation resistance.

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

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

**References:**

1. Almeida, J., "Review of the Development of Cesium Iodide Photocathodes for Application to Large RICH Detectors", *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 367(1-3): 332-336, December 11, 1995. (ISSN: 0168-9002)*

2. Bauer, C., et al., "Recent Results from Diamond Microstrip Detectors," *Nuclear Instruments and Methods in Physics Research, Section A*, 367(1-3): 202-206. December 11, 1995. (ISSN: 0167-0587)*

3. Bellwied, R., et al., "Development of Large Linear Silicon Drift Detectors for the STAR Experiment at RHIC," *Nuclear Instruments and Methods in Physics Research, Section A*, 377 (2-3): 387-392, August 1,1996. (ISSN: 0167-0587)*

4. Bromley, D. A., "Evolution and Use of Nuclear Detectors and Systems," *Nuclear Instruments and Methods in Physics Research, Section A*, 162(1-3, pt. I): 1-8, June 1-15, 1979. (ISSN: 0029-554X)*

5. *Conceptual Design Report for the Solenoidal Tracker at the Relativistic Heavy Ion Collider (RHIC)*, Lawrence Berkeley Laboratory, June 15, 1992. (Report No. LBL-PUB-5347) (NTIS Order No. DE92041174)

6. Contin, A., et al., "New Results in Optical Fiber Cherenkov Calorimetry," *Nuclear Instruments and Methods in Physics Research, Section A*, 367(1-3): 271-275, December 11, 1995. (ISSN: 0168-9002)*

7. Davinson, T., et al., "Development of a Silicon Strip Detector Array for Nuclear Structure Physics," *Nuclear Instruments and Methods in Physics Research, Section A*, 288(1): 245-249, March 1, 1990. (ISSN: 0168-9002)*

8. Deleplanque, M. A., et al., "GRETA [Gamma Ray Energy Tracking Array]: Utilizing New Concepts in Gamma Ray Detection," *Nuclear Instruments and Methods in Physics Research, Section A*, 430(2-3): 292-310, July 1999. (ISSN: 0167-0587) {Also available on web under "Documents" at http://greta.lbl.gov/ *

9. Eisen, Y., et al., "CdTe and CdZnTe Gamma Ray Detectors for Medical and Industrial Imaging Systems," *Nuclear Instruments and Methods in Physics Research, Section A*, 428(1): 158-176, June 1999. (ISSN: 0168-9002)*

10. Gatti, E., et al., "Silicon Drift Chambers - First Results and Optimum Processing of Signals," *Nuclear Instruments and Methods in Physics research, Section A*, 226 (1): 129-141, September 15, 1984. (ISSN: 0167-0587)*

11. Grupen, C., *Particle Detectors*, New York: Cambridge University Press, 1996. (ISBN: 0-521-55216-8)

12. Hershcovitch, A., "A Plasma Window for Vacuum-Atmosphere Interface and Focusing Lens of Sources for Nonvacuum Ion Material Modification," from a paper presented at the *7th International Conference on Ion Sources, Taormina, Italy, September 7-13, 1997, Review of Scientific Instruments*, 69(2): 868-873, February1998. (ISSN: 0034-6748)

13. Knowles, P. E., "A Windowless Frozen Hydrogen Target System," *Nuclear Instruments and Methods in Physics Research, Section A*, 368(3): 604-610, January 11, 1996. (ISSN: 0168-9002)*

14. Libby, B., et al., "Particle Identification in TEC/TRD Prototypes for the PHENIX Detector at RHIC." *Nuclear Instruments and Methods in Physics Research, Section A*, 367(1-3): 244-247, December 11, 1995. (ISSN: 0168-9002)*

15. Meier, J., et al., "Energy Sensitive Detection of Heavy Ions with Transition Edge Calorimeters," *Journal of Low Temperature Physics*, 93(3-4): 231-238, November 1993. (ISSN: 0022-2291)

16. *PHENIX Conceptual Design Report: an Experiment to be Performed at the Brookhaven National Laboratory Relativistic Heavy ion Collider.* Brookhaven National Laboratory, January 29, 1993. (Report No. BNL-48922) (NTIS Order No. DE93015759)

17. Sellin, P. J., et al., "A Double Sided Silicon Strip Detector System for Proton Radioactivity Studies," *Nuclear Instruments and Methods in Physics Research, Section A*, 311 (1-2): 217-223, January 1, 1992. (ISSN: 0168-9002)*

18. *Proceedings of the International Symposium on Solid State Detectors for the 21st Century, Osaka, Japan, December 4-6, Nuclear Instruments and Methods in Physics Research*, A 436(1-2) October 21, 1999. (ISSN: 0168-9002)*

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

19. Vetter, K., et al., "Three-Dimensional Position Sensitivity in Two-Dimensionally Segmented HP-Ge Detectors," *Nuclear Instruments and Methods in Physics Research, Section A*, 452(1-2): 223-238, September 21, 2000. (ISSN: 0167-0587)*

* Full text available on the Web from ScienceDirect at: http://www.sciencedirect.com/science/publications/journal/physics

## 38. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

The DOE seeks developments in detector instrumentation electronics with improved energy, position, and timing resolution; sensitivity; rate capability; stability; dynamic range; durability; and background suppression. Of particular interest is innovative readout electronics for use with the nuclear physics detectors described in Topic 37. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

**a. Advances in Digital Electronics**—Digital signal processing electronics is needed to replace analog signal processing in nuclear physics applications. Grant applications are sought to develop: (1) digital processors that include the features of current main amplifiers, such as pile-up rejection and ballistic deficit correction; (2) digital pulse processing electronics for solid state detectors, in particular for position sensitive detectors; and (3) fast digital processing electronics in order to determine the position of interaction points (of particle collisions) to an accuracy smaller than the size of the detector segments (note that it will be important to analyze the pulse shape of the preamplifier pulses).

**b. Integrated Circuits**—Grant applications are sought for special purpose, custom designed integrated circuits and for circuits and systems for rapidly processing data from highly segmented, position-sensitive 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, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample-and-hold integrated circuits; and (3) a constant fraction discriminator that has uniform response for low and high energy gamma-rays, as well as a discriminator that can separate neutrons and gamma rays. These circuits should be fast, low-cost, high-density, and configurable in software for thresholds, gains, etc. Compatibility with one of the widely used module interconnection standards (FASTBUS, VMEbus, etc.) also would be highly desirable, as would low power consumption, advanced packaging, adaptability to a large number of multiple channels, and commercial digitizing circuits (ICs, ADCs, FADCs, and TDCs) made available as multi-channel chips (4X, 8X, 16X...).

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

**c. Advanced Devices and Systems**—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 include bus systems, data links, event handlers, multiple processors, and fast buffered time and analog digitizers. Generalized software and hardware packages, with improved graphic and visualization capabilities, for the acquisition and analysis of nuclear physics research data are also of interest.

**d. Manufacturing and Assembly Techniques**—Grant applications are sought to develop: (1) manufacturing techniques for large, thin, multiple-layer printed circuit boards (PCBs) with plated-through holes with dimensions from 2m x 2m to 5m x 5m and 100-200 micron thick (these PCBs would have use in cathode pad chambers, cathode strip chambers, time projection chamber cathode boards, etc); (2) techniques to add plated-through holes in a reliable, robust way to large rolls of metallized mylar or kapton (with application to such detectors as time expansion chambers or large cathode strip chambers); and (3) miniaturization

techniques for connectors and cables with 5 times to 10 times the density of standard interdensity connectors.

Lastly, many next generation detectors will have highly segmented electrode geometries with 5-5000 channels per square centimeter, covering areas up to several square meters. Because conventional packaging and assembly technology cannot be used at these high densities, grant applications are sought for: (1) advanced interconnect technologies that address the issues of high density, area-array connections including modularity, reliability, repair/rework, and electrical parasites; (2) technology for aggregating and transporting the signals (analog and digital) generated by the front-end electronics, and for distributing and conditioning power and common signals (clock, reset, etc.); (3) advanced high-bandwidth data links for detectors that generate extremely high data volumes (e.g. >500Gb/s); and (4) new low-cost methods for efficient cooling of on-detector electronics.

**References:**


1. *1999 IEEE Nuclear Science Symposium and Medical Imaging Conference, Seattle, WA, October 24-30, 1999*, IEEE Transactions on Nuclear Science. 47 (3 pt.2): 729-1257, June 2000. (ISSN: 0018-9499)

2. *Conceptual Design Report for the Solenoidal Tracker at RHIC*, Lawrence Berkeley Laboratory, June 15, 1992. (Report No. LBL-PUB-5347) (NTIS Order No. DE92041174)*

3. Kroeger, R. A., et al., "Charge Sensitive Preamplifier and Pulse Shaper Using CMOS Process for Germanium Spectroscopy," *IEEE Transactions on Nuclear Science*, 42(4, pt.1): 921-924, August 1995. (ISSN: 0018-9499)

4. *PHENIX Conceptual Design Report An Experiment to be Performed at the Brookhaven National Laboratory Relativistic Heavy Ion Collider,* Brookhaven National Laboratory, January 29, 1993. (Report No. BNL-48922) (NTIS Order No. DE93015759)*

5. *Proceedings of the International Symposium on Solid State Detectors for the 21st Century, Osaka, Japan, December 4-6*, Nuclear Instruments and Methods in Physics Research, Section A, 436(1-2), October 21, 1999. (ISSN: 0168-9002)**

6. Makdisi, Y. and Stevens, A. J., *Proceedings of the Symposium on Relativistic Heavy Ion Collider Detector R& D, Upton, NY, October 10-11, 1991*, Brookhaven National Laboratory, 1991. (Report No. BNL-52321) (NTIS Order No. DE93010855/HDM)*

7. Lee, I-Y., ed., *Proceedings of the Workshop on the Experimental Equipment for an Advanced ISOL Facility, Berkeley, CA, July 22-25, 1998*, Lawrence Berkeley National Laboratory (LBNL), August 15, 1998. (Report No. LBNL-42138) (OSTI Document No. DE00760328) (Available via interlibrary loan only. Cannot be loaned to individuals. Contact LBNL Library at: Library@lbl.gov) (1999 summary of proceedings, including recommendations, available on the Web at: http://www.osti.gov/servlets/purl/760328-zVOiiK/webviewable/)

8. Simpson, M. L., et al., "An Integrated, CMOS, Constant-Fraction Timing Discriminator for Multichannel Detector Systems," *IEEE Transactions on Nuclear Science*, 42(4, pt. 1): 762-766, August 1995. (ISSN: 0018-9499)

9. Thomas, S. L., et al., "A Modular Amplifier System for the Readout of Silicon Strip Detectors," *Nuclear Instruments and Methods in Physics Research, Section A*, 288(1): 212-218, March 1, 1990. (ISSN: 0168-9002)**


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

** Available from ScienceDirect at: http://www.sciencedirect.com/science/publications/journal/physics.

## 39. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Large scale data storage and processing systems are needed to store, retrieve, and process data from experiments conducted at large facilities, such as Brookhaven National Laboratory's Relativistic Heavy Ion Collider and the Thomas Jefferson National Accelerator Facility. These data, produced at rates of 100 MB/sec or more, result in the annual production of

data sets on the order of several hundred Terabytes (TB). Similar data management systems are required to support the needs for non-accelerator nuclear physics experiments. The investigation and intelligent storage of these large amounts of data represents the largest computational challenge in experimental nuclear physics. **Grant applications are sought only in the following subtopics:**

**a. Data Handling and Distribution**—Large scale data storage and access, as well as processing and distribution systems are required for the scientific programs being carried out at Nuclear Physics facilities across the nation. These facilities produce 100s of TB of data per year. Many 10s of TB of data per year are distributed to many institutions around the U.S. and other countries for analysis by the scientific collaborators. Grant applications are sought for (1) hardware and software techniques to improve the effectiveness and reduce the costs of handling such large data volumes, (2) hardware and software techniques to improve the effectiveness of the computational and data grids (see reference [3] for these uses); and (3) novel approaches to data mining, automatic structuring of data and information, and facilitated information retrieval – in particular, methods for improving the storage and retrieval of data from array-type detector systems (like the Gammasphere), which consist of a large number of nearly identical detectors.

Projections of the cost of data storage media show that magnetic disk media will soon be competitive with magnetic tape for storing large volumes of data. However, because most of the data in nuclear physics datasets is accessed infrequently, the infrastructure costs of operating a petabyte disk storage system could be prohibitive compared to magnetic tape systems that keep all disk drives powered and spinning. Therefore, grant applications are sought for new techniques leading to petabyte-scale magnetic disk systems, with low cost and low power usage, that scale linearly with the amount of data accessed rather than with the total storage capacity.

**b. Novel and Improved Methods for Using Scientific Databases**—In general, data produced by nuclear physics experiments consist of two types, event data and auxiliary data. Although auxiliary data (which describe the state of the detector, accelerator, and other environmental aspects) are usually stored in databases, this has not been traditionally been the case for event data. However, over the last decade, there has been interest in using databases to store all, or at least selected parts, of the event data in databases. Therefore, grant applications are sought for: (1) novel methods for using databases to store and access all aspects of nuclear experimental data; (2) software that would make nuclear physics databases easier to use; and (3) methods for using databases that would allow nuclear physics data to be available to a wider audience, i.e., beyond the researchers that initially obtained the data.

**c. Distributed Collaborative Infrastructure**—Over the last couple of decades the typical experimental nuclear physics collaboration has grown from a handful of physicists to hundreds of physicists and engineers. Many collaborators are not permanently stationed at the location where the experiment is taking place, and therefore it is often difficult for them to fully contribute to the experiment and the analysis of the experimental results. Also, the shear size of the collaboration makes it difficult, even for collaborators at the experimental site, to effectively interact and disseminate information. The World Wide Web (WWW) was initially created to address these issues, but today the problem has grown to a magnitude, where just using the WWW is not enough. Therefore, grant applications are sought for: (1) client-server frameworks and Web tools for creating collaborative environments, facilitating the remote participation of detector experts at the data collection stage, and allowing collaborators to remotely monitor experiments, while still preserving the highest degree of safety and security; (2) computer system components and supporting software incorporating the use of Quality-of-Service features generally available in wide area networks; (3) software to support data systems distributed over a wide area network; and (4) framework, interconnects, and other peripherals to allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual.

**References:**


1. Firestone, R. B., "Nuclear Structure and Decay Data in the Electronic Age," *Journal of Radioanalytical and Nuclear Chemistry*, 243(1): 77-86, January, 2000. (ISSN: 0236-5731).

2. Foster, I. and Kesselman, C., *The Grid: Blueprint for a New Computing Infrastructure*, Morgan Kaufmann Publishers, 1998. (ISBN 1558604758)

3. Maurer, S. M., et al., "Science's Neglected Legacy," *Nature*, 405(6783): 117-120, May 11, 2000. (ISSN: 0028-0836)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

4. *Off-Line Computing for RHIC*, Brookhaven National Laboratory, July 20, 1997. (Available on the Web at: http://www.rarf.riken.go.jp/rarf/rhic/rhic-cc-j/. To view, select ps or pdf to right of title.)

5. *Proceedings of the International Conference on Computing in High Energy Physics, Berlin, Germany, April 7-11, 1997.* (Proceedings available on Web at http://www.ifh.de/CHEP97/chep97.htm)

## PROGRAM AREA OVERVIEW
## ADVANCED SCIENTIFIC COMPUTING RESEARCH

http://www.sc.doe.gov/production/octr/index.html

The Office of Advanced Scientific Computing Research (ASCR) supports research in computational technology and subprograms that underlie a variety of Department of Energy missions.

ASCR's primary mission, carried out by the Mathematical, Information, and Computational Sciences subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex phenomena important to the Department of Energy. To accomplish this mission the program fosters and supports fundamental research in advanced scientific computing - applied mathematics, computer science, and networking - and operates supercomputer, networking, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently run these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research provides the techniques to link the data producers; e.g., supercomputers and large experimental facilities with scientists who need access to the data. The two topics that follow support this scientific computing mission.

### 40. HIGH PERFORMANCE NETWORKS

Emerging science experiments in the DOE are expected to generate several petabytes of data, which will be transferred to geographically distributed terascale computing facilities for analysis and visualization by thousands of scientists across the world. In addition, many emerging energy research problems require coordinated access to distributed resources – people, data, computers, and facilities. Unlike today's Internet that is optimized for low-speed web applications, this new emerging distributed terascale scientific computing environment calls for ultra-high-speed networks – networks that can deliver terabits/sec throughput to science applications. This topic is focused on the development of ultra-high-speed transport protocols and network interfaces to support terabits networks and on technology to support coordinated resource sharing across those networks. Grant applications must address scalability issues associated with proposed approaches by demonstrating how the resulting system will be operated from OC-48 to OC-192 (Optical Carrier levels 48 to 192). **Grant applications are sought only in the following subtopics:**

**a. Ultra High-Speed Transport Protocols**—Grant applications are sought to develop radical new approaches to transport protocols – TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) – to be used in overlay optical networks. Such transport protocols, preferably all-optical, must be capable of delivering and sustaining multi-Gigabits/sec throughput to high-end scientific applications – in particular, high-speed data transfer applications.

**b. Smart High-Speed Network Interface Cards**—Grant applications are sought to develop intelligent, high-speed Network Interface Cards (NICs) to perform transport protocol off-loading at ultra-high-speed for emerging network technologies such as 10 GigE (Gigabit Ethernet) and all-optical lambda networks. Adapters using this technique would improve host processor efficiency, increase data throughput, and reduce latency. The emergence of fast, cheap, embedded processors present an opportunity for inexpensive processing to occur on the network interface.

**c. High-Speed Intrusion Detection Systems**—Grant applications are sought to develop high-speed, real-time

*Please note: (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

intrusion detection systems capable of handling OC-48 and OC-192 traffic. These new intrusion detection systems should be automated with Artificial Intelligence (AI) techniques such as fuzzy logic, neural networks, and genetic algorithms to perform computer-assisted intrusion detection and corrective actions.

**References:**


1. *ESnet: The Energy Sciences Network,* U.S. DOE, Office of Science, http://www.es.net

2. Feng, W. and Tinnakornsrisuphap, P., "The Failure of TCP in High-Performance Computational Grids," *SC 2000: High-Performance Networking and Computing Conference*, November 2000. (URL: http://public.lanl.gov/radiant/website/pubs/traffic/sc00.pdf

3. Fisk, M. and Feng, W., "Dynamic Right-Sizing: TCP Flow-Control Adaptation," poster at the *14th Annual ACM/IEEE SC2001 Conference*, November 2001. (URL: http://public.lanl.gov/mfisk/papers/drs-sc01-poster.pdf)

4. Floyd, S., *HighSpeed TCP for Large Congestion Windows*, Internet Engineering Task Force (IETF) Draft, August 2002. (URL: http://www.ietf.org/internet-drafts/draft-floyd-tcp-highspeed-01.txt

5. *IEEE P802.3ae 10Gb/s Ethernet Task Force* Institute of Electrical and Electronics Engineers, Inc., March 2002 http://grouper.ieee.org/groups/802/3/ae/public/index.html

6. *IETF RFC2823: PPP Over Simple Data Link (SDL) Using SONET/SDH with ATM-Like Framing,* Internet Society, May 2000 http://www.faqs.org/rfcs/rfc2823.html

7. *National Coordination Office for Information Technology R&D,* http://www.itrd.gov

8. *Net100,* http://www.net100.org

9. *The WEB100 Project*, http://www.web100.org

10. Tinnakornsrisuphap, P., et al., "On the Burstiness of the TCP Congestion-Control Mechanism in a Distributed Computing System," *20th International Conference on Distributed Computing Systems (ICDCS'00)*, April 2000. (URL: http://public.lanl.gov/radiant/website/pubs/traffic/icdcs00-tcp.pdf)

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


## 41. SCALABLE MIDDLEWARE AND GRID TECHNOLOGIES

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

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

**b. Scalable Grid Technologies**—Grant applications are sought to develop scalable grid technologies to support the emerging distributed computing network that provides dependable, consistent, pervasive, scaleable, and efficient access to various resources integrated into a distributed infrastructure that can be accessed wherever and whenever by DOE scientists. These resources

include visualization systems, computer systems, data storage and archive systems, and scientific instruments. Areas of interest include, but are not limited to, collaborative visualization systems, collaborative problem solving services, application level fast data transfer toolkits, real-time analysis, group collaboration, co-scheduling distributed resources, grid accounting and billing mechanisms, data management tools, science portals, on-line instrumentation, and fast data transfer management services.

**References:**


1. *DOE Science Grid,* U.S. DOE Office of Science http://doesciencegrid.org/

2. Foster, I. and Kasselman, C., eds., *The Grid: Blueprint for a New Computing Infrastructure,* San Francisco, CA: Morrgan Kaufmann Publishers, 1999. (ISBN: 1-55860-475-8)

3. *Global Grid Forum (GFF)* http://www.globalgridforum.com/

4. Globus Project: Related Papers http://www.globus.org/research/papers.html

5. *Particle Physics Data Grid,* U.S. DOE Office of Science, http://www.ppdg.net

6. *SciDAC (Scientific Discovery through Advanced Computing),* U.S. DOE Office of Science http://www.scidac.org

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


## PROGRAM AREA OVERVIEW
## HIGH ENERGY PHYSICS

http://www.er.doe.gov/henp/index.htm

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

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

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

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

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

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

## 42. HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

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

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

**a. High-Speed Electronic Instrumentation**—Grant applications are sought to develop components, electronics, systems, and instrumentation modules as follows:

(1) Special purpose chips and devices are sought for use in the internal circuitry employed in large particle detectors. Desirable features include low noise, low power consumption, high packing density, radiation resistance, very high response speed, and/or high adaptability to situations requiring multiple parallel channels. Desirable functions include amplifiers, counters, analog pulse storage devices, decoders, encoders, analog-to-digital converters, controllers, and communications interface devices.

(2) Circuits and systems are sought for rapidly processing data from particle detectors such as proportional wire chambers, scintillation counters, silicon microstrip detectors, particle calorimeters, and Cerenkov counters. Representative processing functions and circuits include low noise pulse amplifiers and preamplifiers, high speed counters (>300 MHz), and time-to-amplitude converters. Compatibility with one of the widely used module interconnection standards (e.g., FASTBUS, or VMEbus) is highly desirable, as would be low power consumption, high component density, and/or adaptability to large numbers of multiple channels.

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

(4) Much of the electronics instrumentation in use in high energy physics is packaged in one of the international module inter-connection standards (e.g., FASTBUS, or VMEbus). Therefore, grant applications are sought for modules that will provide capabilities not previously available, for substantial performance enhancement to existing types of modules, and for components, devices, or systems that will enhance or significantly extend the capability or functionality of one of the standard systems. Examples include large and/or fast buffer memories, single module computer systems (either general purpose or special purpose), display modules, interconnection systems, communication modules and systems, and disk-drive interface modules.

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

**c. Distributed Collaborative Infrastructure and Distributed Data Management and Analysis Frameworks**—Advanced computational tools and software are needed to strengthen the ability of dispersed particle physics researchers to collaborate and to address problems related to the acquisition, handling, storage, analysis, and visualization of large datasets by these distributed collaborations. Grant applications are sought to develop: (1) client-server frameworks and Web tools for creating collaborative environments, facilitating remote participation of detector experts at the data collection stage and allowing collaborators to remotely monitor experiments; (2) software project management tools; (3) computer system components and supporting software incorporating the use of Quality of Service features generally available in wide area networks; (4) portable systems to hold very large collections of data of the type created in connection with the operation of very large detectors, along with data management tools; (5) visualization and software environments appropriate for physics analysis; (6) software to support data systems distributed over a wide area network; (7) framework, interconnects, and other peripherals which allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual; and/or (8) software development tools for the production of computer software to meet identified problems related to distributed, large scale software development, configuration management, and data analysis. For (8), approaches of interest include distributed portable testing and Computer Aided Software Engineering (CASE), including configuration management tools for a portable, distributed environment; (9) Web tools for remote data selection ("skimming"); and (10) neural nets for optimization of data cuts and pattern recognition.

**References:**


1. *1991 Nuclear Science Symposium and Medical Imaging Conference, Santa Fe, New Mexico, November 2-9, 1991*, IEEE Transactions on Nuclear Science, 39(4): 486-1179, August 1992. (ISSN: 0018-9499)

2. Abashian, A., ed., *Particles and Fields--1983, Blacksburg, VA, September 15, 1983*, New York: American Institute of Physics, 1984. (AIP Conference Proceedings No. 112) (DOE Report No. CONF-8309196) (NTIS Order No. TI84008600)*

3. *ATLAS Collaboration, ATLAS Technical Proposal for a General-Purpose pp Experiment at the Large Hadron Collider at CERN*, Geneva, Switzerland: CERN - European Laboratory for Particle Physics, December 1994. (Document No. CERN/LHCC/94-43) (Contact Scientific Information Service, CERN, CH-1211 Geneva 23 Switzerland. URL: http://library.cern.ch/index.html)

4. *ATLAS DAQ, EF, LVL2 and DCS Technical Progress Report and Workplan* CERN--European Laboratory for Particle Physics http://atlasinfo.cern.ch/Atlas/GROUPS/DAQTRIG/TPR/tpr.html

5. Bromley, D. A., "Evolution and Use of Nuclear Detectors and Systems," *Nuclear Instruments and Methods in Physics Research*, 162(1-3, pt. I): 1-8, 1979. (ISSN: 0029-554X)

6. *Documents Relating to US-CMS Software and Computing,* CERN--European Laboratory for Particle Physics http://cmsdoc.cern.ch/~cmscan/uscmssw/documents.html

7. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry: Proceedings of the 14th International Conference, Denton, TX, November 6-9, 1996*, 2 vols., New York: American Institute of Physics, May 1997. (AIP Conference Proceedings No. 392) (ISBN: 1-563-96652-2) (Available from Springer-Verlag New York, Inc. Telephone: 800-777-4643. Web site: http://www.springer-ny.com)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

8. *Fifth Conference on Real-Time Computer Applications in Nuclear, Particle, and Plasma Physics, San Francisco, CA, May 12-14, 1987*, IEEE Transactions on Nuclear Science, NS-34(4), August 1987. (ISSN: 0018-9499)

9. *IEEE Standard FASTBUS Modular High-Speed Data Acquisition and Control System: An American National Standard*, 1993. (ISBN: 1559373962)

10. *IEEE Standard for VMEbus Extensions for Instrumentation*, VXI-Bus, September 1992. (ISBN: 1559372605)

11. *IEEE Standard Modular Instrumentation and Digital Interface System (CAMAC)*, February 26, 1982. (ISBN: 1559376325)

12. *IEEE Standard for a Versatile Backplane Bus: VMEbus*, October 1985. (ISBN: 1559376740)

13. Kleinknecht, K., *Detectors for Particle Radiation*, Cambridge, MA: Cambridge University Press, 1986. (ISBN: 0521304245)

14. Perkins, D. H., *An Introduction to High Energy Physics*, Reading, MA, Addison-Wesley, 1982. (ISBN: 0-201-05757-3)

15. Regler, M., et al., *Data Analysis Techniques in High Energy Physics Experiments*, Cambridge, MA: Cambridge University Press, 1990. (ISBN: 0521341957)

* Available from National Technology Information Service. See Solicitation General Information and Guidelines, section 7.1.

## 43. HIGH ENERGY PHYSICS DETECTORS

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

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

**a. Particle Detection and Identification Devices—** Grant applications are sought for novel devices in the areas of charged and neutral particle detection and identification. Examples include, but are not limited to, semiconductor particle detectors (silicon, CVD diamond, or other semiconductors), light-emitting particle detectors (scintillating materials including fibers and crystals or Cherenkov radiators), photosensitive detectors that could be used with light-emitting detectors (photomultipliers, micro-channel plates, photosensitive semiconductors), gas or liquid-filled chambers (used for particle tracking or in electromagnetic or hadronic calorimeters, Cherenkov or transition radiation detectors).

The proposed devices must be explicitly related to future high-energy physics experiments, either accelerator or non-accelerator based, or to future uses in particle accelerators. Relevant potential improvements over existing devices and techniques must be discussed explicitly (e.g., radiation hardness, energy, position, and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, cost). 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.

**b. Detector Support and Integration Components**—High energy physics 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 high-energy physics 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 are also sought for alignment and cooling systems.

**References:**


1. Abashian, A., ed., "Particles and Fields - 1983," *AIP Conference Proceedings No. 112; Particles and Fields, Subseries No. 32*, American Institute of Physics, 1984. (NTIS Order No. T184008600. Available from National Technology Information Service. See Solicitation Information and Guidelines, section 7.1)

2. Abe, F., et al., "The CDF Detector: An Overview," *Nuclear Instruments & Methods in Physics Research, Section A—Accelerators, Spectrometers, Detectors and Associated Equipment*, 271(3): 387-403, 1988. (ISSN: 0168-9002)

3. Amidei, D., et al., "The Silicon Vertex Detector of the Collider Detector at Fermilab," *Nuclear Instruments & Methods in Physics Research, Section A, Accelerators,Spectrometers, Detectors and Associated Equipment*, 350(1-2):73-130, October 15, 1994. (ISSN: 0168-9002)

4. Bock, R. K. and Regler, M., *Data Analysis Techniques in High Energy Physics Experiments*, Cambridge, MA: Cambridge University Press, 1990. (ISBN: 0-521-34195-7)

5. Bromley, D. A., "Evolution and Use of Nuclear Detectors and Systems," *Nuclear Instruments and Methods in Physics Research*, 162(1-3): 1-8, June 15, 1979. (ISSN:0029-554X)

6. Cline, D. B., "Low-Energy Ways to Observe High-Energy Phenomena," *Scientific American*, 271(3): 40-47, September 1994. (ISSN: 0036-8733)

7. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry: Proceedings of the 15th International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 4-7, 1998*, New York: American Institute of Physics, 1999. (AIP Conference Proceedings No. 475) (ISBN: 1-56396-825-8) (Available from Springer- Verlag New York, Inc. Web site: http://www.springer-ny.com)

8. Kleinknecht, K., *Detectors for Particle Radiation*, Cambridge, MA: Cambridge University Press, 1986. (ISBN: 0-521-30424-5)

9. Litke, A. M. and Schwarz, A. S., "The Silicon Microstrip Detector," *Scientific American*, 272(5): 76-81, May 1995. (ISSN: 0036-8733)

10. Perkins, D. H., *An Introduction to High Energy Physics*, Addison-Wesley Longman, 1982. (ISBN: 0-201-05757-3)


## 44. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The Department of Energy (DOE) High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in the following areas: (1) new concepts for acceleration, (2) novel device and instrumentation development, (3) inexpensive electron sources, and (4) computer software that will contribute to overall advances in accelerator technology applicable to high energy physics research. Relevance to applications in high energy physics must be explicitly described in the submitted grant applications. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 36. Grant applications that propose using resources of a third party (such as a DOE Laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. New Concepts for Acceleration**—Grant applications are sought to develop new or improved acceleration concepts. Designs should provide very high gradient (>100 MeV/m for electrons or >10 MeV/m for protons) acceleration of intense bunches of particles, or efficient

acceleration of intense (>50 mA) low energy (of order <20 MeV) proton beams. One possible concept might include the fabrication of accelerator structures from materials such as Si or $SiO_2$, using integrated circuit technology; in this case, power sources might include lasers in the wavelength range from 1 to 2.5 micrometers. For all proposed concepts, stageability, beam stability, manufacturability, and high wall plug-to-beam power efficiency must be addressed in detail. Grant applications must also address the marketability of any systems, technologies, and devices to be developed.

**b. Novel Device and Instrumentation Development**—Grant applications are sought for the development of electromagnetic, permanent magnet, or silicon microcircuit-based charged particle optical elements for particle beam focusing. Examples include, but are not limited to, dipoles, quadrupoles, higher order multipole correctors for use in electron linear accelerators, and solenoids for use in electron-beam or ion-beam sources or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.1 to 10 cm. In these optical elements, permanent magnets or hybrid magnets incorporating magnetic materials that have very high residual magnetization, radiation resistance, and thermal stability (low variation of field strength with temperature) are of particular interest.

Grant applications are also sought for: (1) novel charged particle beam monitors to measure the transverse or longitudinal charge distribution or emittance, or phase-space distributions of small radius (0.1 micrometers to 5 millimeters diameter), short length (10 micrometers to 10 millimeters) relativistic electron or ion beams; (2) devices capable of measuring and recording the Schottky or transition radiation spectrum of these beams (proposed techniques should be nondestructive or minimally perturbative to the beams monitored and have computer-compatible readouts); and (3) lasers for laser-accelerator applications that provide substantial improvements over currently available lasers in one or more of the following parameters: longer wavelengths (2 to 2.5 micrometers for use with Si transmissive optics), very short wavelengths (< 200 nanometers) with low mode numbers (M-squared < 100) and high pulse energy (> 0.1 J) for photo-ionized plasma sources, higher power, higher repetition rates, or shorter pulse widths.

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

Grant applications are also sought for the development of novel devices and instrumentation for use in the cooling (transverse and longitudinal emittance reduction) of muon beams. Approaches of interest include the development of: concepts or devices for ionization cooling, including emittance exchange processes; instrumentation for muon cooling channels with muon intensities of $10^{12}$ muons/pulse; or fast (of order 10 picosecond) timing detectors for muon cooling experiments with low muon intensity (of order $10^5$ muons/second).

**c. Inexpensive High Quality Electron Sources**—Grant applications are sought for the design and prototype fabrication of small, inexpensive (<$1 million) electron sources for use in advanced accelerator R&D laboratory experiments. The following parameters are target values for accelerator research experiments: (1) energy range of 5 to 35 MeV providing, at a minimum, on the order of $10^9$ electrons in a bunch less than 5 picoseconds long; (2) normalized transverse beam emittance less than or equal to 5 pi mm-mrad; and (3) pulse repetition rate greater than 10 Hz. Grant applications are also sought for significantly lower bunch charges, energies, and emittances – yet with comparable or greater peak currents and significantly higher repetition rates – for bunches from a matrix cathode. In addition, grant applications are sought to develop a bright DC/RF photocathode electron source that combines a pulsed high electric field DC gun and a high field rf accelerator, operates at a repetition rate of several kHz, and has electron bunch specifications that are similar to those listed above.

Grant applications also are sought for the development of radio frequency photocathodes (robust, with quantum efficiencies >0.1 percent) or other novel rf gun technologies operating at output electron beam energies >3 MeV. Laser or electron driven systems for such guns are also sought.

***Please note:*** *(1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

Finally, grant applications are sought for research and development on electron sources to be used as polarized beam injectors for linear accelerators, including linear colliders. These sources should be gated with pulses or pulse trains larger than 0.1 microsecond at about 100-200 pulses per second, and on semiconductor photocathode sources of electrons with polarization greater than or on the order of 80 percent and energy in the range of a few volts to several hundred kilovolts. In addition, intensity stability <1 percent is required for polarized beams in pulsed linacs.

**d. Computer Software**—Grant applications are solicited for developing new or improved computer software specifically for the design or study of charged particle beam optical systems, accelerator systems, or accelerator components. Such applications should incorporate the innovative development of user-friendly interfaces with emphasis on graphical user interfaces and windows. Grant applications are also solicited for the conversion of existing codes to incorporate such interfaces, provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate.

Grant applications also are sought for improved simulation packages for injectors or photoinjectors. Specific examples include: (1) improved space-charge algorithms; (2) improved algorithms for computing self-consistently the effects of wakefields and coherent synchrotron radiation on the detailed beam dynamics; (3) improved fully 3-D algorithms for the modeling of transversely asymmetric beams; and (4) explicit end-to-end simulations that provide for more accurate beam-quality calculations in full injector systems.

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

**References:**


1. Bisognano, J. J. and Mondelli, A. A., eds., *Computational Accelerator Physics, Williamsburg, VA, September 24-27,1996*, American Institute of Physics (AIP), May 1997. (AIP Conference Proceedings No. 391) (ISBN: 1-56396-671-9)*

2. Chao, A. and Tigner, M., eds., *Handbook of Accelerator Physics and Engineering*, River Edge, NJ: World Scientific, 1999. (ISBN: 981-02-3858-4)

3. Chattopadhyay, S., et al., eds., *Advanced Accelerator Concepts: Seventh Workshop, Lake Tahoe, CA, October 12-18, 1996*, American Institute of Physics, 1997. (AIP Conference Proceedings No. 398) (ISBN: 1-56396-697-2)*

4. Chattopadhyay, S., et al., eds., *Nonlinear and Collective Phenomena in Beam Physics-1998 ICFA Workshop, Archidosso, Italy, September 1-5, 1998*, American Institute of Physics, 1999. (AIP Conference Proceedings No. 468) (ISBN: 1-56396-862-2)*

5. Colestock, P. and Kelley, S., eds., *Advanced Accelerator Concepts Workshop, Santa Fe, NM, June 10-16, 2000*, American Institute of Physics, 2001. (AIP Conference Proceedings No. 569) (ISBN: 0-7354-0005-9)*

6. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry: Proceedings of the Sixteenth International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 1-5, 2000*, New York: American Institute of Physics, 2001. (AIP Conference Proceedings No. 576) (ISBN: 0-7354-0015-6)*

7. Hettel, R. O., et al., eds., *Beam Instrumentation Workshop, Stanford, CA, May 3-7, 1998*, American Institute of Physics, 1998. (AIP Conference Proceedings No. 451) (ISBN: 1-56396-794-4)*

8. Jacobs, K. and Sibley III, R., eds., *Beam Instrumentation Workshop 2000: Ninth Workshop, Cambridge, MA, May 8-11, 2000*, American Institute of Physics, 2000. (AIP Conference Proceedings No. 546) (ISBN: 1-56396-975-0)*

9. Ko, K. and Ryne, R., *Proceedings of the International Computational Accelerator Physics Conference, Monterey, CA, September 14-18, 1998.* (Document No. SLAC-R-580) (Available on Web at: http://www.slac.stanford.edu/econf/C980914.)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

10. Kurokawa, S. et al., eds., *Beam Measurement: Proceedings of the Joint US-CERN-Japan-Russia School on Particle Accelerators, Montreux and CERN, Switzerland, May 11-20, 1998*, River Edge, NJ: World Scientific, 1999. (ISBN: 981-02-3881-9)

11. Kurokawa, S. et al., eds., *Frontiers of Accelerator Technology: Proceedings of the Joint US-CERN-Japan International School, Maui, HI, November 3-9, 1994*, River Edge, NJ: World Scientific, 1996. (ISBN: 981-02-2537-7)

12. Lawson, W., et al., eds., *Advanced Accelerator Concepts: Eighth Workshop, Baltimore, MD, July 6-11, 1998*, American Institute of Physics, 1999. (AIP Conference Proceedings No. 472) (ISBN: 1-56396-794-4)*

13. Lee, S. Y., *Accelerator Physics*, River Edge, NJ: World Scientific, 1999. (ISBN: 981-02-3710-3)

14. Lee, S. Y., ed., *Space Charge Dominated Beams and Applications of High Brightness Beams, Bloomington, IN, October 10-13, 1995*, American Institute of Physics, 1996. (AIP Conference Proceedings No. 377) (ISBN: 1-56396-625-5) *

15. Lucas, P. and Webber, S., eds., *Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, June 18-22, 2001*, Institute of Electrical and Electronics Engineers, Inc., 2001. (ISBN: 0-7803-7191-7)

16. Parsa, Z., ed., *Future High Energy Colliders, Institute for Theoretical Physics, Santa Barbara, CA, October 21-25, 1996*, American Institute of Physics, 1997. (AIP Conference Proceedings No. 397) (ISBN: 1-56396-729-4)*

17. Parsa, Z., ed., *New Modes of Particle Acceleration-Techniques and Sources, Institute for Theoretical Physics, Santa Barbara, CA, August 19-23, 1996*, American Institute of Physics, 1997. (AIP Conference Proceedings No. 396) (ISBN: 1-56396-728-6)*

18. Rosenzweig, J. and Serafini, L., eds., *The Physics of High Brightness Beams: Proceedings of the 2nd ICFA Advanced Accelerator Workshop, Los Angeles, CA, November 9-12, 1999*, River Edge, NJ: World Scientific, 2000. (ISBN: 981-02-4422-3)

19. Schoessow, P., ed., *Advanced Accelerator Concepi Fontana, WI, June 12-18, 1994*, American Institu of Physics, 1995. (AIP Conference Proceedings N 335) (ISBN: 1-56396-476-7)*

* Available from Springer-Verlag New York, In Telephone: 800-809-2247. Websit http://www.springer-ny.com

## 45. RADIO FREQUENCY ACCELERATO TECHNOLOGY FOR HIGH ENERG ACCELERATORS AND COLLIDERS

The Department of Energy (DOE) High Energy Physi program supports a broad research and developme (R&D) effort in the science, engineering, and technolo of charged particle accelerators, storage rings, ar associated apparatus. Advanced R&D is needed support of this research in (1) high gradient accelerat structures, (2) high peak power radio frequency (r technologies, and (3) new concepts for low-cost, ve efficient, pulse power modulators. Relevance applications in high energy physics must be explicit described.

Advanced accelerator R&D more appropriate applications in nuclear physics is specifically exclude from this topic and should be submitted under Topic 3 Grant applications that propose using resources of a thi party (such as a DOE laboratory) must include, in th application, a letter of certification from an authorize official of that organization. **Grant applications ar sought only in the following subtopics:**

**a. Radio Frequency Acceleration Structures**—Gra applications are sought for research on very hig gradient rf accelerating structures, normal superconducting, for use in accelerators and storag rings. Gradients >100 MeV/m for electrons and >1 MeV/m for protons in normal cavities are of particul interest, as are means for suppressing unwanted highe order modes and reducing costs. For use in muo accelerator R&D, achieving gradients of 5-10 MeV/ for cavities with frequencies between 20 and 200 MHz also of interest. Means for achieving unloaded voltag gradients >40 MeV/m and reducing costs superconducting cavities are also of interest, as a methods for reducing surface breakdown an multipactoring (such as surface coatings or speci geometries) and for suppressing unwanted higher ord modes. Grant applications should be applicable

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

devices operating at frequencies from 1.2 to 100 GHz or between 20 and 300 MHz for muon accelerators.

**b. Radio Frequency Power for University and Government Linear Accelerators**—Grant applications are sought for new concepts, high-power rf components, and instrumentation for producing high peak power (>75 MW at 11 GHz, appropriately reduced when scaled to higher frequencies), narrow band, low duty-cycle, low pulse repetition frequency (approximately 0.1 to 1 kHz) pulsed rf amplifiers for application to upgrading future large electron/positron linear colliders. Potential electrical efficiencies greater than 45 percent are considered essential. Of particular interest are innovations related to cost saving, manufacturability, and electrical efficiency. For example:

(1) One way of providing rf power is the cluster klystron, a device consisting of a "cluster" of separate magnetron gun driven klystrons that share a common focusing field and accelerating gap. Such a device could give high total pulsed power with relatively small individual beam currents, and thus be capable of high efficiency. The use of magnetron guns allows the many beams to be enclosed in a compact space, and have modulation anodes that allow the current to be switched, thus eliminating the need for a pulsed high-voltage modulator. Therefore, grant applications are sought to develop cluster klystrons, as well as highly stable magnetron guns for cluster klystrons.

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

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

Upgrades to the next generation linear collider will require many rf power handling components which are not presently available, e.g., rf windows, couplers, mode transformers, rf loads, and high power rings capable of operating at high pulse powers (20 - 100 MW), high frequencies (11 - 100 GHz), and pulse lengths of several microseconds. Grant applications are sought for passive and active rf components such as over-moded mode converters from rectangular to circular waveguide and vice versa, high-power rf windows, circulators, isolators, switches, and high-power rf pulse compression methods for use in future linear colliders.

**c. New Concepts or Components for Pulsed Power Modulators and Energy Storage**—Most rf power sources for future university or government linear colliders require high peak-power pulse modulators of considerably higher efficiency than presently available. Grant applications are sought for new types of modulators in the 400 kV - 1 MV range for driving currents of 200 - 800 A, with pulse lengths of 0.2 – 4.0 microseconds, and rise- and fall-times of less than 0.5 microsecond. Innovation related to cost saving, manufacturability, and electrical efficiency in modulators is especially important. Modulators with improved voltage control for rf phase stability in some alternate rf power systems are also sought. Of particular interest is the development of cathode modulators for driving single or double sheet beam diode gun klystrons, based on the Marx multiplier principle. This design should produce 400-500 kV, 3.2 microsecond pulses; have rise and fall times less than 600 nsec; and be compact and cost competitive compared to present cathode pulse modulator schemes.

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

Grant applications are also sought to develop improved high power solid-state switches for pulse power switching. For some applications, requirements will include the ability to switch high current pulses (2-5 kAmps) at voltage levels of 2 to 6 kV with switching times of less than 300 nsec. These switches must handle very high di/dt (20 kAmps/microsecond) at low duty cycle (<0.1 percent).

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

Grant applications are also solicited for the design, development, and computer modeling of a multiple, concentric, high-voltage cable that provides primary pulse energy storage for a klystron electron gun when pulsed, while also connecting the klystron to a remote grid pulser and power supply system. This power scheme would use a high voltage, multiple concentric conductor cable to store the energy delivered during the short, several hundred nanosecond, klystron cathode pulses. The pulse repetition frequency of these pulses is on the order of 100-300 Hz. The dynamic impedance of the klystron during the pulse is on the order of 750 ohms. A typical cable impedance for this sort of cable design is 35 ohms. Thus, if the cable is initially charged to 5 percent over required cathode voltage, then when the grid is pulsed and the cathode delivers full current, the cable voltage on the load end should drop to the required cathode voltage, and this voltage should be maintained until the wave-front, launched on the cable as the result of the grid switched cathode current, travels to the other end of the cable and returns to the load end. At this time, the grid would turn off the cathode current, canceling the returning wave. This dictates that the cable must have an electrical length of exactly half the cathode pulse width. The cable would then recharge slowly during the interpulse period. The cable must have good DC high voltage stand-off characteristics, while also having very low loss and dispersion functions for the traveling waves. Power systems incorporating such high voltage cables are also desired.

Lastly, grant applications are sought to develop and optimize high reliability, high energy density energy storage capacitors for future solid state pulse power systems. The capacitors must: (1) deliver high peak pulse current (5 - 8 kAmps) in the partial discharge region (less than 10 percent voltage droop during pulse), (2) be designed with very low inductance connections to allow fast rise and fall time discharge without ringing (di/dt ~ 20 kAmps/microsecond), and (3) be packaged to meet the requirements of high power solid state board layouts and have minimum production cost.

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

Note: See Topic 47 regarding the solicitation of grant applications for components and systems that target the presently envisioned X-band Linear Collider.

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

**References:**

1. Carlsten, B. E., ed., *High Energy Density and High Power RF: 5th Workshop on High Density and High Power RF, Snowbird, Utah, October 1-5, 2001*, New York: American Institute of Physics, 2002. (AIP Conference Proceedings No. 625) (ISBN: 0-7354-0078-4)*

2. Chattopadhyay, S., et al., eds., *Advanced Accelerator Concepts: Seventh Workshop, Lake Tahoe, CA, October 12-18, 1996*, New York: American Institute of Physics, 1997. (AIP Conference Proceedings No. 398) (ISBN: 1-56396-697-2)*

3. Cline, D. B., ed., "Muon Collider Studies," *Physics Potential and Development of $\mu^+$-$\mu^-$ Colliders, Fourth International Conference, San Francisco, CA, December 1997*, pp. 183-344, American Institute of Physics, 1998. (AIP Conference Proceedings No. 441) (ISBN: 1-56396-723-5)*

4. Cline, D. B., ed., *Physics Potential and Development of Muon Colliders and Neutrino Factories: Fifth International Conference, San Francisco, CA, December 15-17, 1999*, New York: American Institute of Physics, 2000. (AIP Conference Proceedings No. 542) (ISBN: 1-56396-970-X)

5. Colestock, P. and Kelley, S., eds., *Advanced Accelerator Concepts Workshop, Santa Fe, NM, June 10-16, 2000*, New York: American Institute of Physics, 2001. (AIP Conference Proceedings No. 569) (ISBN: 0-7354-0005-9)*

6. Dolgashev, V. A. and Tantawi, S. G., "2-D Simulation of High-Efficiency Cross-Field RF Power Sources," *XX International Linac Conference, (Linac 2000), Monterey, CA, August 21-25, 2000*, Stanford Linear Accelerator Center, September 2000. (Report No. SLAC-PUB-8603) (Full *Linac 2000* proceedings available on the Web at: http://www.slac.stanford.edu/econf/C000821/. For Dolgashev and Tantawi paper, select "Author List" on menu at left, scroll down to Dolgashev, and select "THA06.")

7. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry: Proceedings of the Sixteenth International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 1-5, 2000*, New York: American Institute of Physics, 2001. (AIP Conference Proceedings No. 576) (ISBN: 0-7354-0015-6)*

8. Fernow, R. C., ed., *Pulsed RF Sources for Linear Colliders Workshop, Montauk, NY, October 2-7, 1994*, New York: American Institute of Physics Press, 1995. (AIP Conference Proceedings No. 337) (ISBN: 1563964082)*

9. King, B., ed., *Colliders and Collider Physics at the Highest Energies: Muon Colliders at 10 TeV to 100 TeV: HEMC '99 Workshop, Montauk, NY, Sept. 27-Oct. 1, 1999*, New York: American Institute of Physics, 2000. (AIP Conference Proceedings No. 530) (ISBN: 1-56396-953-X)

10. Lawson, W., et al., eds., *Advanced Accelerator Concepts Workshop, Baltimore, MD, July 6-11 1998*, New York: American Institute of Physics 1999. (AIP Conference Proceedings No. 472) (ISBN: 1-56396-889-4)*

11. Luccio, A. and MacKay, W., eds., *Proceedings of the 1999 Particle Accelerator Conference, New York, NY, March 27-April 2, 1999*, Institute of Electrical and Electronics Engineers, Inc., 1999 (ISBN: 0-7803-5575-X) (IEEE Catalogue No 99CH36366)

12. Phillips, R. M., ed., *High Energy Density Microwaves, Pajaro Dunes, CA, October 1998*, New York: American Institute of Physics, 1999. (AIP Conference Proceedings No. 474) (ISBN: 1-56396-796-0)*

13. Schoessow, P., ed., *Advanced Accelerator Concepts Workshop, Fontana, WI, June 12-18, 1994*, New York: American Institute of Physics, 1995. (AIP Conference Proceedings No. 335) (ISBN: 1-56396-476-7)*

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

## 46. 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 (1) high-field superconductor and (2) superconducting magnet technologies. This topic addresses only those superconductor and superconducting magnet development technologies that support dipoles, quadrupoles, and higher order multipole

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

corrector magnets for use in accelerators, storage rings, and charged particle beam transport systems. Grant applications that propose the use of third party resources (such as a DOE laboratory) must include in the application a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. High-Field Superconductor Technology**—Grant applications are sought for new or improved materials and related processing techniques for high critical-current, high critical-field conductors for the production of low alternating current (AC) loss conductors used in very high-field magnets. Grant applications for the improvement of starting raw materials are of particular interest. While improvements are sought for magnets above 8 Tesla, the engineering goal for the near future (7 to 10 years) is at least 15 Tesla. Applications must demonstrate such property improvements as higher critical-current densities and higher critical fields, as well as manageable degradation of these properties as a function of applied strain. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K. Process improvements must result in equivalent performance at reduced cost. Advanced conductor fabrication techniques of interest also include methods to utilize high aspect ratio stranded conductors or tape geometries in particle accelerator applications. Materials of interest include: niobium-titanium, ternary niobium-titanium alloys, the so-called "A-15" compounds (e.g., niobium-tin and niobium-aluminum), and oxide (high temperature) superconductors. Regarding oxide superconductors, a minimum current density of 1200 A/mm$^2$ (not cm$^2$) in the superconductor itself and a minimum current density of 250 A/mm$^2$ over a total conductor cross section, at 12 Tesla minimum and 4.2 K, must be achieved. Grant applications that address the development of A-15 and oxide superconductors must deliver a sufficient amount of material to for winding and testing in small dipole or quadrupole magnets.

Because high performance niobium-titanium (NbTi) alloys operating above 8 Tesla appear to be required for focusing quadrupole magnets or for "low field" graded windings in higher field dipoles, grant applications are sought for NbTi composite superconductors with properties optimized at the higher field portion of the short sample curve. These grant applications must focus on conductors that will be acceptable for accelerator magnets.

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

**b. Superconducting Magnet Technology**—Grant applications are sought to develop: (1) improved instrumentation to measure properties (such as local strain, temperature, and magnetic field) which are directly applicable to the testing of superconducting magnets; (2) improved current leads based on high-temperature superconductors for application to high-field accelerator magnets, which have requirements that include current level at 5 kA or greater, stability, low heat leak, and good quench performance; (3) alternative designs, to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets, that may be more compatible with the more fragile A-15 and the oxide, high-field superconductors; or (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.

**References:**


1. Breon, Susan, et al., eds., "Advances in Cryogenic Engineering Materials," *Proceedings of the Cryogenic Engineering Conference, Madison, Wisconsin, 2001*, Vol. 47 A & B, New York: AIP, 2002. (ISBN: 0-7354-0059-8)

2. Cifarelli, L. and Maritato, L., eds., *Superconducting Materials for High Energy Colliders: Proceedings of the 38th Workshop of the INFN Eloisatron Project, Erice, Italy, October 19-25, 1999*, River Edge, NJ: World Scientific, 2001. (ISBN: 981-02-4319-7)

3. Duggan, J. L. and Morgan, I. L., eds., *Application of Accelerators in Research and Industry: Proceedings of the Sixteenth International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 1-5, 2000*, New York: American Institute of Physics, 2001. (AIP Conference Proceedings No. 576) (ISBN: 0-7354-0015-6) (Available from Springer-Verlag New York, Inc. Telephone: 800-809-2247 Web site: http://www.springer-ny.com)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

4. *Luccio, A. and MacKay, W., eds., Proceedings of the 1999 Particle Accelerator Conference, New York, NY, March 27-April 2, 1999,* Institute of Electrical and Electronics Engineers, Inc., 1999. (ISBN: 0-7803-5575-X)

5. Mess, K.-H., et al., *Superconducting Accelerator Magnets*, River Edge, NJ: World Scientific, 1996. (ISBN: 981-02-2790-6)

6. *The 1998 Applied Superconductivity Conference, Palm Desert, CA, September 13-18, 1998,* IEEE Transactions on Applied Superconductivity, 3 Parts, 9(2), June 1999. (ISSN: 1051-8223)

7. *The 2000 Applied Superconductivity Conference, Virginia Beach, VA, September 17-22, 2000,* IEEE Transactions on Applied Superconductivity, 3 Parts, 11(1), March 2001. (ISSN: 1051-8223)

## 47. TECHNOLOGIES FOR THE NEXT-GENERATION ELECTRON-POSITRON LINEAR COLLIDER

The DOE High Energy Physics program supports research and development (R&D) of technologies for a TeV-scale electron-positron linear collider that would use normal-conducting X-Band (11.4 GHz) microwave power. This collider will be five to ten times the energy of present-generation linear accelerators. This topic addresses near-to-medium term developments to enhance performance and reliability and/or to reduce costs of accelerator components and infrastructures. Applications should demonstrate relevance to these issues. Grant applications that propose the use of third party resources (such as a DOE Laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. Direct Current (DC) and Pulsed Power Supplies Modulators and Components**—Advances are needed in various aspects of pulse modulators and associated components to drive klystrons in both injector and main linac applications. Grant applications are sought for:

(1) Ultra-Reliable Capacitors of ~10-25 microfarads at 2.5 to ~6 kV to provide stored energy for partial discharge, on-off switch modulator configurations. Requirements include low loss, low inductance, high power density to minimize volume, MTBF >100,000 hours, and low cost. Long lifetime is a priority because the large numbers of such units in the modulator designs will dominate modulator reliability.

(2) High Voltage Pulse Transformers with low leakage inductance and minimized core loss, for use in solid-state-switch driven modulators with a load-matching transformer. The modulators will drive a pair of X-band klystrons at 180 Hz with ~500 kV, 520 A peak and 3 microseconds pulse-length, or drive an S-band klystron in the injector at 180 Hz with 380 kV, 800 A peak, and at least 6 (possibly up to 16) microseconds pulse-length. Rise/fall times of less than 300 ns and droop/ripple of less than 2 percent are desired. Transformers must operate in oil and be compact, efficient, and cost-effective to manufacture.

Additional information can be obtained from Ray Larsen at SLAC (e-mail: larsen@SLAC.Stanford.EDU; phone: 650-926-4907; fax: 650-926-5124).

**b. Manufacturing Processes and Support Technology for Microwave Power**—The transmission of high power, X-band microwaves to the high-energy, X-band linear accelerators may utilize oversized, multi-mode components and waveguides with non-standard cross sections, evacuated to 10 nTorr pressure. Components for such functions as manipulating microwave modes or introducing mechanical flexibility may be irregularly shaped. They also require demanding tolerances on internal dimensions (mils), surface finishes (microns), leak rates ($10^{-12}$ Torr-liter/sec/cm$^2$), rf voltage hold-off (40 MV per meter), and surface conductivity (at least as good as aluminum). For these components, conventional manufacturing processes such as investment casting or electroforming are not adequate. Therefore, grant applications are sought to develop appropriate techniques or manufacturing processes to economically produce these microwave components in large batches of identical parts.

Grant applications are also sought to develop or advance "first cut" (net shape or near net shape) manufacturing processes for mass production of high-conductivity (100 percent dense), oxygen-free (ASTM F.68 Metallographic Class I) copper components used in ultra-high vacuum (UHV) (equilibrium vapor pressure <1 nTorr at 300 C), high-power microwave applications. For these applications, mechanical tolerances of 50-100 micrometers must be achieved. Of particular interest are

***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

grant applications that seek to develop or advance processes for precision machining subsequent to net shaping, with dimensional and flatness tolerances of one micrometer and surface finishes of 10 nanometer (rms). Other areas of interest include (but are not limited to): powdered metallurgy with copper plating; precision mechanical measurement device(s) for RF component fabrication; development of microwave Quality Control techniques for X-band cell manufacturing, able to resolve shifts of 0.5 MHz in cell resonant frequency due to multidimensional errors; and surface treatments for RF components and assemblies. Lastly, manufacturing processes for the mass production of ultra-high vacuum, high-power parts made from stainless steel, aluminum, or copper alloys are also of interest, provided that tolerances and applicability are similar to those listed above. All grant applications must demonstrate significant cost reduction over conventional techniques (such as current numerically controlled machining methods). Additional information can be provided by Gregg Kobliska or Harry Carter at Fermilab (Kobliska: e-mail: gregg@fnal.gov; phone: 630-840-4893; fax: 630-840-nnnn; Carter: e-mail: hfcarter@fnal.gov phone: 630-840-2458; fax: 630-840-8022).

Finally, to support the generation and transmission of high power microwaves, grant applications are sought to develop: (1) a microwave circulator and/or active switch with high efficiency for multi-megawatt power levels at 11.4 GHz [see reference 7]; (2) robust, reliable techniques for distributed pumping and/or for suppression of surface field emission in components and waveguides; (3) robust, reliable techniques for the joining components and waveguide sections in the accelerator housing [see reference 8]; or (4) new permanent magnet focusing structures with reduced cost or improved reliability for X- or S band klystrons or for X-band crossed-field amplifiers. Further information can be obtained from Sami Tantawi at SLAC (e-mail: tantawi@SLAC.Stanford.EDU; phone 650-926-4454; fax: 650-926-5368).

**c. UHV Manufacturing Techniques for Damping Ring Cavities and Vacuum Chambers**—Grant applications are sought to develop ultra-high vacuum (UHV) manufacturing techniques for low-cost, reliable fabrication of UHF-band radiofrequency accelerating cavities with damped higher-order modes for use in damping rings. Fabrication of the cavity and its penetrations has in the past been performed by multi-axis milling of oxygen-free, high-conductivity copper - an expensive process. More cost-effective candidate techniques include stereolithography, casting, electroforming, plunge-EDM, etc. Methods are also required for providing cooling channels that can be accessed from the exterior of the cavity. Methods such as plasma deposition over machined or formed channels, or brazed tubing, may be investigated (in preference to existing electroplating techniques). The joining of parts by electron-beam welding is also of interest.

Grant applications are also sought to develop improved low-cost techniques for the fabrication of damping-ring UHV aluminum vacuum chambers with detailed, non-circular cross-sections and outgassing rates of $10^{-12}$ Torr-liter/sec/cm$^2$ or less at room temperature. Machining tolerances are generally approximately ±1 mm over the length of the structure, with detailed features requiring tolerances of approximately ±100 micrometer to be added in a subsequent process. In order to reduce the effective surface area, and thus outgassing rate, the chambers may be extruded, with a final machined surface finish. Other details of the manufacturing process, such as the cleaning process and the choice of machining lubricant are also critical in producing and maintaining low outgassing rates. Other needs include (1) improved methods of joining the vacuum chambers to the stainless steel flanges with UHV-compatible techniques, and (2) the development of a method and equipment to directly measure outgassing rates, in order to evaluate the chamber manufacturing techniques described above. For the latter, requirements include measurements of $10^{-12}$ Torr-liter/sec/cm$^2$ or less at room temperature for multiple samples of aluminum or other metals, and minimal sample sizes to lower the costs of preparation.

Further information on can be obtained from Marc Ross at the Stanford Linear Accelerator Center (e-mail: mcrec@SLAC.Stanford.EDU; phone: 650-926-3526; fax: 650-926-5124).

**d. Focusing and Auxiliary Systems**—As a potentially more economical and reliable alternative to DC electromagnets, permanent magnets are under consideration. Grant applications are sought to develop engineering design and evaluation techniques applicable to permanent magnets used in linear colliders, and for a highly reliable permanent magnet quadrupole that is remotely tunable over a range of ±20 percent relative to its nominal integrated focusing gradient (taking about 10 seconds). The quadrupole must be magnetically stable, with less than 1.4 micrometers of magnetic center shift. These specifications require symmetry and stability not previously sought from permanent magnets and greatly influence the magnetic and mechanical design of the

quadrupole. A typical quadrupole will have 13-mm-diameter aperture, 430-mm length, and 0.8-Tesla pole-tip field. The operating environment that is contemplated is 10,000 Rads per year, and stable temperature near 90°F. See reference 1 for more information on this subject. Further information can be obtained from John Cornuelle, SLAC (e-mail: johnc@SLAC.Stanford.EDU; phone: 650-926-2545; fax: 650-926-5124).

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

Grant applications also are sought to develop one or both of two types of precision translation actuators suitable for integration into hundreds of mover systems (each with several degrees of freedom) for the spatial adjustment of beam line components in the radiation environment of a high-energy linear accelerator that is several miles long. The continuous adjustment of linac components will require more than 10,000 actuators (of Type 1) with load capacity of 250 kg, resolution of 1 micron, range of plus or minus 1 mm, stability of 1 micron per day, maximum speed of 2 mm/min, power of 20 W at full speed, and average unit cost below $200. The final focusing magnets will require tens of even more precise actuators (Type 2) with 1000 kg load capacity, 0.1 micron resolution, plus or minus 0.5 mm range, 0.5 micron per day stability, and 100 W power at full speed. The latter type should be functional at 4 Tesla and 3 degrees Kelvin, and may cost more than the Type 1 actuators. Both types should use less than 2 W when static and should fail safely when power is removed. Localized position readout would be desirable as an independent supplement to the precision measurements by beam position monitors. Further information can be obtained from Gordon Bowden at SLAC, (e-mail: gbb@SLAC.Stanford.EDU; phone: 650-926-2991; fax: 650-926-5368.

Finally, sensors and electronic devices are needed for measurement and control. Grant applications are sought to develop: (1) robust, non-contact position sensors based on radiation resistant materials (e.g. eddy-current sensors) and produced at low cost in large quantities (the critical range of motion is ~1 mm with resolution and repeatability of ~100 nm; and (2) custom integrated electronic circuits that can be transferred to a radiation-hard process suitable for devices to be used in an accelerator housing – specifically, circuits are needed for controlling beam position monitors; ion-pump controllers; low-level rf mixers, demodulators, multiplexers, and digitizers; and magnet-mover controllers. Further information can be obtained from Ray Larsen at SLAC (e-mail: larsen@SLAC.Stanford.EDU; phone: 650-926-4907; fax: 650-926-5124).

**References:**


1. *2001 Report on the Next Linear Collider: A Report submitted to Snowmass 2001.* By NLC Collaboration. SLAC-R-571, 157 pp. Prepared for APS / DPF / DPB *Summer Study on the Future of Particle Physics (Snowmass 2001), Snowmass, Colorado, June 30-July 21, 2001.* (Available on the Web at: http://www-project.slac.stanford.edu/lc/wkshp/snowmass2001/)

2. Bellomo, P., et al., "A Novel Approach to Increasing the Reliability of Accelerator Magnets," *IEEE Transactions on Applied Superconductivity*, 10(1): 284-287, March 2000. (ISSN: 1051-8223)

3. Dolgashev, V. A. and Tantawi, S. G., "2-D Simulation of High-Efficiency Cross-Field RF Power Sources," *XX International Linac Conference, (Linac 2000), Monterey, CA, August 21-25, 2000*, Stanford Linear Accelerator Center,

4. September 2000. (Report No. SLAC-PUB-8603) (Full *Linac 2000* proceedings available at: http://www.slac.stanford.edu/econf/C000821/. For Dolgashev and Tantawi paper, select "Author List" on menu at left, scroll down to Dolgashev, and select "THA06.")

5. *Lehman DOE Review, Stanford Linear Accelerator Center, Menlo Park, CA, May 24-28, 1999.* (Available on the Web at: http://www-project.slac.stanford.edu/lc/nlc-tech.html. Starting at "NLC Technical," select "Technical Rev. 1999." Scroll down to "May 24-28" and select "Lehman DOE Review.")

6. Loew, G., ed., *International Linear Collider Technical Review Committee Report*, 1995. (Available on the Web at: http://www.slac.stanford.edu/xorg/ilc-trc/toc.html)


***Please note:** (1) The technical topics are to be interpreted literally, and all grant applications must respond to a particular topic and subtopic. (2) Last year only 1 out of 4 grant applications were awarded; only those applications with high scientific/technical quality will be competitive.*

7. *Next Linear Collider Modulator Workshops, Stanford Linear Accelerator Center, Menlo Park, CA, June 23-25, 1999.* (Available on the Web at: http://www-project.slac.stanford.edu/lc/local/Reviews/modulators/workshop/mod-wrkshop.htm)

8. *Proceedings of the 7th International Workshop on Linear Colliders (LC 97), Zvenigorod, Russia, Sept. 29-Oct. 3, 1997.* (Available on the Web at: http://www.desy.de/conferences/LC97/proceed/html/proceed.htm)

9. *Proceedings of the 8th International Workshop on Linear Colliders (LC 99), Frascati, Italy, October 21-26, 1999.* (Available on the Web at http://wwwsis.lnf.infn.it/lc99/)

10. Tantawi, S. G., "New Development in RF Pulse Compression," *20th International Linac Conference, Monterey, CA, August 21-25, 2000*, Stanford Linear Accelerator Center, 2000. (Report No. SLAC-PUB-8582) ( http://arXiv.org/pdf/physics/0008204/)

11. Volk, J. T., et al., "Adjustable Permanent Quadrupoles for the Next Linear Collider," *Proceedings of the [IEEE] 2001 Particle Accelerator Conference, (PAC 2001), Chicago, Illinois, June 18-22, 2001*, 1:217-219, IEEE, 2001. (Available on the Web at: http://fnalpubs.fnal.gov/archive/2001/conf/Conf-01-093.pdf)

12. *Zeroth-Order Design Report for the Next Linear Collider*, a report submitted to Snowmass 1996. By NLC collaboration, SLAC-R-474, 1120 pp. (Available on the Web at: http://www.slac.stanford.edu/pubs/slacreports/slac-r-474.html)

* See section 7.1.