PROGRAM AREA OVERVIEW: OFFICE OF ADVANCED SCIENTIFIC COMPUTING RESEARCH

The primary mission of the Advanced Scientific Computing Research (ASCR) program is to discover, develop, and deploy computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to the Department of Energy. A particular challenge of this program is fulfilling the science potential of emerging computing systems and other novel computing architectures, which will require numerous significant modifications to today's tools and techniques to deliver on the promise of exascale science. To accomplish this mission, ASCR funds research at public and private institutions and at DOE laboratories to foster and support fundamental research in applied mathematics, computer science, and high-performance networks. In addition, ASCR supports multidisciplinary science activities under a computational science partnership program involving technical programs within the Office of Science and throughout the Department of Energy.

ASCR also operates high-performance computing (HPC) centers and related facilities, and maintains a high-speed network infrastructure (ESnet) at Lawrence Berkeley National Laboratory (LBNL) to support computational science research activities. The HPC facilities include the Oak Ridge Leadership Computing Facility (OLCF) at Oak Ridge National Laboratory (ORNL), the Argonne Leadership Computing Facility (ALCF) at Argonne National Laboratory (ANL), and the National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory (LBNL).

ASCR supports research on applied computational sciences in the following areas:

- Applied and Computational Mathematics - to develop the mathematical algorithms, tools, and libraries to model complex physical and biological systems.
- High-performance Computing Science - to develop scalable systems software and programming models, and to enable computational scientists to effectively utilize petascale computers to advance science in areas important to the DOE mission.
- Distributed Network Environment - to develop integrated software tools and advanced network services to enable large-scale scientific collaboration and make effective use of distributed computing and science facilities in support of the DOE science mission.
- Applied Computational Sciences Partnership - to achieve breakthroughs in scientific advances via computer simulation technologies that are impossible without interdisciplinary effort.

For additional information regarding the Office of Advanced Scientific Computing Research priorities, click here.

1. ADVANCED DIGITAL NETWORK TECHNOLOGIES AND MIDDLEWARE SERVICES

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Advanced digital network technologies and middleware services play a significant role in the way DOE scientists communicate with peers and collect/process data. Optical networks operating at rates of more than 100 Gbps support the transfer of petabytes of data per day. These networks also peer with commercial

networks allowing scientists remote access to instruments and facilities while also allowing citizens access to the data and knowledge that has been produced. Improvements in the tools and services used to manage and operate this infrastructure are needed to meet the needs of both network operators and users.

Scientific instruments and supercomputer facilities generate, consume, process, and store both raw and analyzed data enabling the discovery of new knowledge. Efforts are underway to scale these computers to support extreme-scale computationally intensive science applications and to deal with increasing volumes and velocities of experimental and observational data. Optical components play a role at all in these systems, ranging from chip-to-chip communications all the way up to wide area networks. Accelerating the development of optical components to meet the data movement needs of unique scientific instruments and computing facilities is a major challenge that this topic addresses. This topic also addresses the higher level middleware services and tools that are needed to turn raw data into actionable knowledge

This topic solicits proposals that address issues related to developing tools and services that report performance problems in a manner suitable for network engineers or application users, developing optical components that can be used to build digital networks or computer interconnect fabrics, or hardening middleware tools and services that deal with Big Data.

a. PerfSONAR Based Network Monitoring Tools and Services

perfSONAR (http://www.perfsonar.net) is a network monitoring architecture developed by the international Research and Education Network (REN) community for developing multi-domain measurement and monitoring services. Using this architecture engineers can deploy tools and services that collect and store unique data values in managed data archives. Other tools and services can then leverage this archived data to analyze and display it in a manner that makes sense to the network operator or end user. As of May 2015, there are over 1400 deployed perfSONAR measurement boxes in the world-wide REN community.

Grant applications are sought to improve the scalability, usability, and deployability of perfSONAR based tools and services. Outstanding issues include, but are not limited to: 1) Scaling: The perfSONAR community expects to scale from thousands to hundreds-of-thousands of deployed measurement boxes. Tools and services are required that can manage dozens to hundreds of measurement boxes in a cost effective manner. 2) Hardware: low-cost hardware solutions that can operate over regional and transcontinental distances at 10 Gbps and beyond are needed. 3) Unique Data Collection: Software tools are needed that collect and store unique data measurements under the supervision of the perfSONAR management service layer. 4) Data Analysis tools: The collected data needs to be analyzed to identify both trend information and performance anomalies. 5) Data Visualization services: Network operators and network users need intuitive displays that show performance or operational information tailored to meet the individuals' needs.

Questions – Contact: Richard Carlson, richard.carlson@science.doe.gov

b. Optical/Photonic Computing and Networking Components

Information processing requirements and capabilities of high performance computing (HPC) and network systems have grown dramatically and the need for increased data transmission rates and bandwidth coupled with lower cost and energy consumption has become a limiting factor in the performance of such

systems. Ready commercially available photonic, silicon photonic, and quantum computing componentry and tools could provide an effective and scalable solutions to current and future HPC and network communication challenges. Optical, photonic or optoelectronic components and technologies have revolutionized all areas of digital communications. Increasing overall systems parallelism, concurrency, and need for energy efficiency have emerged as some of the key challenges. Optical and Photonic devices and componentry could offer the potential for creating system-wide interconnection and computing networks and systems with extremely high bandwidth and energy efficiency. Therefore, commercially available optical, photonic or optoelectronic components and tools could provide an effective and scalable solution to building and operating future extreme-scale computers.

Grant applications are sought to develop and commercialize tools, devices, services, fabrication capabilities, and turnkeys that will accelerate rapid adoption of these technologies and address the emerging need for massive deployment of optical and photonic network and computing infrastructures. Issues include but are not limited to: tools that decrease the cost of terminating or splicing optical cables; ultrafast solid state switching fabrics; photonic devices; optoelectronic devices; and interconnects; reconfigurable optical/photonic converters or encoders; components to test optical signal quality; computing components; or components that operate at 100+ Gigabit per sec line rates.

Questions – Contact: Robinson Pino, robinson.pino@science.doe.gov

c. BigData Technologies

This sub-topic focuses on complex data management technologies that go beyond traditional relational database management systems. The efficient and cost-effective technologies to collect, manage, and analyze distributed BigData is a challenge to many organizations including the scientific community. Database management technologies based traditional relational and hierarchical database systems are proving to be inadequate to deal with BigData complexities (volume, variety, veracity, and velocity), especially when applied to BigData systems in science and engineering. While the primary focus is on the development of tools and services to support complex scientific and engineering data, all sources of complex data are in-scope for this sub-topic. The focus of this sub-topic is on the development of cost-/time-effective commercial grade technologies in the following categories:

- BigData management software-enabling technologies – this includes but are not limited to the development of software tools, algorithms, and turnkey solutions for complex data management such as NOSQL/graph databased to deal with unstructured data in new ways; visualization and data processing tools for unstructured multi-dimensional data, robust tools to test, validate, and remove defects in large unstructured data sets; tools to manage and analyze hybrid structured and unstructured data; BigData security and privacy solutions; BigData as a service systems; high-speed data hardware/software data encryption and reduction systems; and online management and analysis of streaming and text data from instruments or embedded systems

- BigData Network-aware middleware technologies – This includes high-speed network and middleware technologies that enable the collection, archiving, and movement of massive amounts of data within datacenters, data cloud systems, and over Wide Area Networks (WANS). This may include but are not limited to hardware subsystems such high-performance data servers and data transfer nodes, high-speed storage area network (SAN) technologies; network-optimized data cloud services such as virtual storage technologies; and other distributed BigData solutions

Grant applications must ensure that proposed work goes beyond traditional data management system technologies by focusing one or more defining characteristics of BigData (Volume, velocity, veracity, and variety).

Questions – Contact: Thomas Ndousse, thomas.ndousse-fetter@science.doe.gov

d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Richard Carlson, richard.carlson@science.doe.gov

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2. INCREASING ADOPTION OF HPC MODELING AND SIMULATION IN THE ADVANCED MANUFACTURING AND ENGINEERING INDUSTRIES

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Over the past 30 years, The Department of Energy's (DOE) supercomputing program has played an increasingly important role in the scientific discovery process by allowing scientists to create more accurate models of complex systems, simulate problems once thought to be impossible, and analyze the increasing amount of data generated by experiments. Computational Science has become the third pillar of science, along with theory and experimentation. Despite the great potential of modeling and simulation to increase

understanding of a variety of important engineering and manufacturing challenges, High Performance Computing (HPC) has been underutilized.

Application complexity, in both the development and execution phase requires a substantial in-house expertise to fully realize the benefits of the software tool or service. High capital equipment and labor costs can severely limit a company's ability to incorporate HPC into their development process. It should also be recognized that changes in HPC hardware including many-core, multi-core processors, GPU based accerators, and multi-level memory subsystems have made a significant impact on the HPC systems performance and usability. Programming tools and services are required that can hide this hardware complexity without impacting performance.

This topic is specifically focused on bringing HPC solutions and capabilities to the advanced manufacturing and engineering market sectors.

Grant applications are sought in the following subtopics:

a. Turnkey HPC Solutions for Manufacturing and Engineering

HPC modeling and simulation applications are utilized by many industries in their product development cycle, but hurdles remain for wider adoption especially for small and medium sized manufacturing and engineering firms. Some of the hurdles are: overly complex applications, lack of hardware resources, inability to run proof of concept simulations on desktop workstations, solutions that have well developed user interfaces, but are difficult to scale to higher end systems, solutions that are scalable but have poorly developed user interfaces, etc. While many advances have been made in making HPC applications easier to use they are still mostly written with an expert level user in mind.

Grant applications that focus on HPC applications that could be utilized in the advanced manufacturing supply chain, additive manufacturing (3D Printing) processes and Smart Manufacturing are strongly encouraged as well as applications that address the need to have solutions that are easier to learn, test and integrate into the product development cycle by a more general user (one with computational experience, but not necessarily an expert). Issues to be addressed include, but are not limited to: Developing turn-key HPC application solutions, porting HPC software to platforms that have a more reasonable cost vs. current high end systems (this could also include porting to high performance workstations (CPU/GPU) which would provide justification for the procurement of HPC assets or small scale clusters, or to a "cloud" type environment or service), HPC software or hardware as a service (hosted locally or in the "cloud"), near real time modeling and simulation tools, etc.

Questions – Contact: Ceren Susut, Ceren.Susut-Bennett@science.doe.gov

b. Hardening of R&D Code or Software Tools for Industry Use

The Office of Science (SC) Office of Advanced Scientific Computing (ASCR) has invested millions of dollars in the development of HPC software in the areas of modeling and simulation, solvers, and tools. Many of these tools are open source, but are complex "expert" level tools. The expertise required to install, utilize and run these assets poses a significant barrier to many organizations due to the levels of complexity built into them to facilitate scientific discovery and research, but such complexity may not necessarily be required for industrial applications. Grant applications are specifically sought that will take a component or

components of codes developed via the Scientific Discovery through Advanced Computing (SciDAC) program, or other ASCR programs, and "shrink wrap" them into tools that require a lower level of expertise to utilize. This may include Graphical User Interface Designs (GUIs), simplification of user input, decreasing complexity of a code by stripping out components, user support tools/services, or other ways that make the code more widely useable. Applicants may also choose to harden the codes developed by other projects provided that the potential industrial uses support the DOE mission. In addition applicants may choose to strip out code components, harden them and join them with already mature code tools and/or suites of tools to increase the overall toolset and scalability of commercial software.

Questions – Contact: Randall Laviolette, Randall.Laviolette@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Ceren Susut, Ceren.Susut-Bennett@science.doe.gov

Note: In addition to local, cluster, or cloud computing resources, applicants may consider using DOE's Open Science (DOE-SC) Computing facilities, the National Energy Research Scientific Computing Center (NERSC), the Argonne Leadership Computing Facility (ALCF), or the Oak Ridge Leadership Computing Facility (OLCF). Applicants wishing to run at the NERSC (http://www.nersc.gov) facility should send email to "consult@nersc.gov" and inquire about the Education/Startup allocation program. Descriptions of the allocation programs available at the ALCF can be found at http://www.alcf.anl.gov/user-guides/how-get-allocation. Questions concerning allocations on the ALCF can be sent to David Martin, the ALCF center director at "dem@alcf.anl.gov". Descriptions of the allocation programs available at the OLCF are available at http://www.olcf.ornl.gov/support/getting-started/. Questions concerning allocations on the OLCF can be sent to Jack Wells, the OLCF center director at "wellsjc@ornl.gov". Proprietary work may be done at the ALCF and OLCF facilities using a cost recovery model.

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3. HPC CYBERSECURITY

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Large scale distributed and computationally intensive systems, platforms, centers, infrastructure, facilities or applications rely on High Performance Computing (HPC) systems to enable large scale information processing for a multitude of areas such as business, utility, financial, education, scientific, and critical national infrastructure systems that form the backbone of our nation's economy, security, and health. HPC facilities, centers, infrastructure, or resources are designed to be easily accessible by users over the worldwide network, and ensuring effective cybersecurity monitoring, situational awareness, logging, reporting, preventions, remediation, etc, is an increasingly important task. This topic solicits proposals that address cybersecurity challenges involving HPC systems.

Grant applications are sought in the following subtopics:

a. Cybersecurity Technologies

This topic solicits unclassified proposals that will deliver and market commercial products ensuring effective and practical cybersecurity for HPC systems, centers, large scale distributed applications, critical infrastructure, or user facilities. These tools will have the capability to detect, prevent, or analyze attempts to compromise or degrade systems or applications consequently increasing their cybersecurity. Any submitted proposal must be unclassified.

Relevant evaluation metrics may include delivery of potential solutions involving minimizing the overall security overhead required to deal with data parallelism, concurrency, storage and retrieval, hardware heterogeneity, and how to monitor, visualize, categorize, or report cybersecurity challenges effectively. Currently, there exist cybersecurity tools and products that provide security to networks, databases, hosts, clouds, or mobile devices; and some of these existing tools and products could potentially be enhanced or transitioned to help secure HPC, facilities, infrastructure, or large scale distributed systems.

Out of scope proposals for this topic include proposals that do not address the range of desired products mentioned in this specific topic or are primarily focused on: Single node/host-, handheld-, and wireless-based solutions; internet; internet-of-things; basic research; natural language processing; social networks; or encryption.

Questions – Contact: Robinson Pino, robinson.pino@science.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Robinson Pino, robinson.pino@science.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF BASIC ENERGY SCIENCES

The Office of Basic Energy Sciences (BES) supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security. 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 scientific user facilities for the development of novel nanomaterials and for materials characterization through x-ray and neutron scattering; the former is accomplished through five Nanoscale Science Research Centers and the latter is accomplished through the world's largest suite of light source and neutron scattering facilities. These national resources are available free of charge to all researchers based on the quality and importance of proposed nonproprietary experiments.

A major objective of the BES program is to promote the transfer of the results of our basic research to advance and create technologies important to Department of Energy (DOE) missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, the mitigation of the adverse impacts of energy production and use, and future nuclear 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.

For additional information regarding the Office of Basic Energy Sciences priorities, click here.

4. RF GUN AND VACUUM TECHNOLOGIES FOR LIGHT SOURCE FACILITIES

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light sources, free electron lasers, and spallation neutron source user facilities. This topic is specifically focused on the development of small aperture vacuum technology and robust microwave thermionic guns to enhance light source user facilities or enable future upgrades.

Grant applications are sought in the following subtopics:

a. Development of Complex, Integrated 3D Vacuum Chamber Structures

Next generation synchrotron light sources would like to make use of vacuum chambers of a much reduced inner size. There is a concurrent requirement for the egress of both insertion device and bend magnet x-ray radiation [1,2]. X-ray egress from the storage ring vacuum chamber requires tangential branching tubes to connect to the x-ray beam lines [3,4,5,6] and needs to be more space efficient than existing designs to fit into highly packed, optimized magnetic lattices. It is envisioned that these branching egress chambers will need to simultaneously integrate topologically complex radiation absorbers for up to a kW of synchrotron radiation, vacuum pumping port arrays to ensure pressures around a nTorr, beam position

monitor electrodes, temperature monitors, and cooling systems into progressively smaller physical packages [1]. The integrated structures will need to reliably function in the intense radiation environment of a synchrotron without degradation to vacuum quality, or mechanical integrity. We seek proposals for designs incorporating new fabrication technologies to produce these complex UHV structures. Three dimensional printing of metals is one example technology candidate for production. Integration of the photon mask development with NEG surface coating technology is desirable [7,8,9]. Demonstration should include integrated mock-ups with supports, vacuum chambers and joints/bellows, and/or performance tests on existing synchrotrons.

Questions – Contact: Eliane Lessner, eliane.lessner@science.doe.gov

b. Robust Microwave Thermionic Electron Gun

Grant applications are sought for the design, modeling and prototype development of a robust S-band rf thermionic electron gun powered by a 5 MW peak rf power input at a 30 – 100 Hz repetition rate with in-pulse average current of 0.5 -1 A, suitable for compression with an alpha magnet, 2-3 MeV beam energy at the gun exit, normalized r.m.s. emittance of ~5 -10 π mm-mrad and with a robust, maintenance-free cathode insertion mechanism capable of position tuning and locking. It is expected that the gun will supersede performance characteristics and reliability of existing thermionic rf electron guns [1,2,3] and can be used in continuous nonstop operation in the injectors of the synchrotron light sources as well as to support high average power THz sources [4,5].

Questions – Contact: Eliane Lessner, eliane.lessner@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Eliane Lessner, eliane.lessner@science.doe.gov

References: Subtopic a:

1. Steier, C., et al., 2015, Progress of the R&D towards a Diffraction Limited Upgrade of the Advanced Light Source, Proceedings of IPAC2015, TUPMA001 (https://jacowfs.jlab.org/conf/proceedings/IPAC2015/papers/tupma001.pdf)

2. MAX IV Facility, 2010, The MAX IV Laboratory, Lund Sweden, Detailed Design Report on the MAX IV Facility. (https://www.maxiv.se/maxlab/max4/index.html)

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4. Al-Dmour, E., et al., 2013, The Status of the Vacuum Systems of the MAX IV Laboratory, Proceedings of IPAC 2013: Vacuum in Accelerators, Shanghai, China, THPHI043, pp. 3382–3384. (https://accelconf.web.cern.ch/accelconf/IPAC2013/papers/thpfi043.pdf)

5. LNLS, 2013, Sirius Design Report, Brazilian Synchrotron Light Source (LNLS), Campinas, SP, Brazil, p. 106. (http://lnls.cnpem.br/wp-content/uploads/2011/10/SiriusDR_02_Jan-2013.pdf)

6. Seraphim, R., et al., 2015, Vacuum System Design for the SIRIUS Storage Ring, Proceedings of IPAC 2015, WEPMA003 (https://jacowfs.jlab.org/conf/y15/ipac15/prepress/WEPMA003.PDF)

7. Chiggiato, P., and Kersevan, R., 2001, Synchrotron Radiation-induced Desorption from a NEG-coated Vacuum Chamber, Vacuum, Vol. 60, pp 67–72. (http://www.sciencedirect.com/science/article/pii/S0042207X00002475)

8. Hahn, M., 2010, Non-Evaporable Getter Coatings at the European Synchrotron Radiation Facility, Journal of the Vacuum Society of Japan, Volume 53, Issue 8, pp. 493-496. (https://www.jstage.jst.go.jp/article/jvsj2/53/8/53_8_493/_article)

9. Herbeaux, C., et al., 2008, NEG Coated Chambers at Soleil: Technological Issues and Experimental Results, Proceedings of EPAC08, Genoa, Italy, pp. 3711-3713 (https://accelconf.web.cern.ch/accelconf/e08/papers/thpp147.pdf)

References: Subtopic b:

1. E. Tanabe, et. al., *A 2-MeV Microwave Thermionic Gun*, SLAC-PUB-50.54, (1989) (http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-5054.pdf)

2. Borland, M., 1991, *Cavity Design and Beam Simulations for the APS RF Gun*, APS Light Source Note, LS-186, p.15. (http://www.aps.anl.gov/Science/Publications/lsnotes/content/files/APS_1417909.pdf)

3. J. W. Lewellen, et. al., 1998, *Operations of the APS RF Gun*, Proc. Linac 1998, Chicago, pp.863-865. (http://accelconf.web.cern.ch/accelconf/l98/PAPERS/TH4042.PDF)

4. J. W. Lewellen, et. al., 1999, *Hot-Spare Injector for the APS Linac*, Proc. PAC 1999, New York, NY, pp. 1979-1981. (http://accelconf.web.cern.ch/accelconf/p99/AI/AIFRAME.HTM)

5. X-RAY OPTICS TECHNOLOGY FOR LIGHT SOURCE FACILITIES

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

High resolution x-ray focusing optics is important to many spatially resolved techniques at many synchrotron facilities, such as micro x-ray fluorescence, micro-diffraction, and micro-spectroscopy as well as many high resolution laboratory techniques. Important performance attributes include minimum spatial resolution achievable, focusing efficiency, working distance, and energy dependence (or achromatic properties). Currently, leading high resolution x-ray focusing optics includes diffractive zone plate optics and reflective KB mirrors but there are well-known limitations for both optics. One promising solution is the design of single-bounce, axially symmetric mirror optics with parabolic inner profiles capable of focusing x-rays simultaneously

in two orthogonal directions, which may overcome the long focal length limitation of KB mirrors. The advantages of such axially symmetric mirror optics may include short focal length, focal length independent of x-ray energy (achromatic), high focusing efficiency, and large numerical aperture. Advances in fabrication development and metrology open the possibility of fabricating axially symmetric optics with smaller focal sizes and smaller slope errors. The increased availability of axially symmetric mirror optics that reduce the stringent requirements on beamline coherence or divergence would enable the addition of nanoscale focusing techniques to many beamlines currently using x-ray micro-beam techniques in a cost-effective, compact, and simplistic manner without requiring the space and construction difficulties associated with the long beamlines required for KB mirrors. The impact of increased resolution and spatial sensitivity is a straightforward means to enable significant scientific advances for established facilities and many existing beamlines.

Grant applications are sought only in the following subtopics:

a. Development of Single Bounce Monolithic Axially Symmetric X-ray Mirror Optics with Parabolic Surface Profile

We seek proposals for development of single bounce monolithic axially symmetric x-ray mirror optic with parabolic surface profile that is capable of focusing x-rays to a sub-100 nm focal spot with a working distance greater than 10 mm. The principle investigator or the proposing company must have significant prior experience in similar development and adequate facilities for the proposed task. Important features of the optics include minimum figure (slope) error and optic straightness to create a single spot sub 100 nm focus for incident x-ray energies between 2-20 keV. Additional preferences include coating the reflecting surface with appropriate high mass density materials to increase the x-ray critical angle and numerical aperture. If Fast-Track application is proposed, an axially symmetric mirror optic with a focus less than 1 micrometer need to be fabricated and demonstrated.

Questions – Contact: Eliane Lessner, eliane.lessner@science.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Eliane Lessner, eliane.lessner@science.doe.gov

References:

1. Vila-Comamala, J., Jefimovs, K., Pilvi, T., et al*., 2009,* Advanced X-ray Diffractive Optics, Proceedings 9th International Conference on X-ray Microscopy, *Journal of Physics: Conference Series 186*. (http://iopscience.iop.org/1742-6596/186/1/012078/pdf/1742-6596_186_1_012078.pdf)

2. Yamauchi, K., Mimura, H., Kimura, T., et al., 2011, Single-Nanometer Focusing of Hard X-rays by Kirkpatrick–Baez Mirrors, *Journal of Physics: Condensed Matters*, Vol 23. (http://iopscience.iop.org/0953-8984/23/39/394206)

3. Bilderback, D.H., Huang, R., Kazimirov, A., 2003, Monocapillary Optics Developments and Applications, Proceedings of the Denver X-ray Conference, *Advances in X-ray Analysis (AXA),* Vol 46, pp 320-325. (http://www.icdd.com/resources/axa/VOL46/V46_48.pdf)

6. HIGH PERFORMANCE MATERIALS FOR NUCLEAR APPLICATION

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

To achieve energy security and greenhouse gas (GHG) emission reduction objectives, the United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible. Nuclear power will continue to be a key component of a portfolio of technologies that meets our energy goals. Nuclear Energy R&D activities are organized along four main R&D objectives that address challenges to expanding the use of nuclear power: (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understanding and minimization of risks of nuclear proliferation and terrorism.

To support these objectives, the Department of Energy is seeking to advance engineering materials for service in nuclear reactors.

Grant applications are sought in the following subtopics:

a. Specialty Steels and Alloys

Grant applications are sought to develop improvements in radiation-resistant, high-temperature steels and alloys with practical applications for Generation IV reactor systems, such as high-temperature gas- or liquid-cooled systems at 400-850°C. In general, this will be interpreted to mean that those materials which have improved creep strength can be formed and joined, are compatible with one or more high-temperature reactor coolants, and could reasonably be expected to eventually receive ASME Section III qualification for use in nuclear construction.

Questions – Contact: William Corwin, william.corwin@nuclear.energy.gov

b. Ceramic Composites

Grant applications are sought to develop improved design and fabrication methods targeted at reducing cost and/or allowing joining of nuclear-grade SiC-SiC composites that can be used in the Generation IV gas-cooled and liquid fluoride salt-cooled reactors at temperatures up to 850°C. Additional consideration will be given to proposals for SiC-SiC materials and forms that are also compatible for use as fuel cladding.

Questions – Contact: William Corwin, william.corwin@nuclear.energy.gov

c. *In Situ* Mitigation and Repair of Materials Degradation

Grant applications are sought to develop technologies for the *in situ* mitigation and repair of materials degradation in Light Water Reactor systems and components, in order to extend the service life of current light water reactors. Approaches of interest include new techniques for the repair of materials degradation

in metals, concrete, and cables; and methods that can mitigate irradiation and aging effects in existing reactors and components.

Questions – Contact: Sue Lesica, sue.lesica@nuclear.energy.gov

d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Sue Lesica, sue.lesica@nuclear.energy.gov

References:

1. 2010, U.S. Department of Energy, *Nuclear Energy Research and Development Roadmap*, Report to Congress. (http://energy.gov/sites/prod/files/NuclearEnergy_Roadmap_Final.pdf).

2. U.S. DOE Office of Nuclear Energy, Science and Technology, Fuel Cycle Research and Development Program. (http://www.energy.gov/ne/nuclear-reactor-technologies/fuel-cycle-technologies).

3. U.S. DOE Office of Nuclear Energy, Science and Technology, Generation IV Nuclear Energy Systems, Nuclear Reactor Technologies. (http://www.energy.gov/ne/nuclear-reactor-technologies)

4. Greene, S.R., et al., 2010, *Pre-Conceptual Design of a Fluoride-Salt-Cooled Small Modular Advanced High Temperature Reactor (SmAHTR)*, Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-2010/199 (http://info.ornl.gov/sites/publications/files/Pub26178.pdf).

5. U.S. DOE Office of Nuclear Energy, Light Water Reactor Sustainability (LWRS) Program. (http://www.energy.gov/ne/nuclear-reactor-technologies/light-water-reactor-sustainability-lwrs-program)

7. HIGH EFFICIENCY MATERIALS FOR SOLID-STATE LIGHTING

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Significant technological advancements in semiconductor materials used to manufacture Light Emitting Diodes (LEDs) for general illumination products have produced remarkable improvements in device performance, lifetime and stability along with sizeable reductions in manufacturing costs. Similarly, comparable advancements in electronic organic materials used in Organic Light Emitting Diodes (OLEDs) have also been realized since the initial introduction of white phosphorescent devices over two decades ago. These impressive advancements in materials science and in contributing fields such as engineering, physics and chemistry, have helped to successfully introduce very energy efficient and high quality white light sources to practical general illumination products at affordable costs. While these advancements are both technically advanced and have unquestionably helped to make the solid-state transformation in general illumination a

reality, development of vital new materials are required to harvest the full economic and performance potential of these transformative lighting technologies.

There are notable opportunities for significant cost reductions and product performance improvements possible with the advent of new materials across a wide spectrum of solid-state lighting (SSL) technologies. It is widely believed that special scientific challenges associated with each of these materials systems remain and are specifically of interest under this topic. The following subtask descriptions highlight a few opportunities that are of special interest to the DOE's Solid-State Lighting program. Much more technical information about these high priority research and development challenges can be found on the program's comprehensive website: http://www1.eere.energy.gov/buildings/ssl/ in the form of numerous technical topical reports, roundtable summaries and program roadmaps.

Grant applications are sought in the following subtopics:

a. Efficiency and Performance Advancements Phosphor Systems

Many constituent materials are used in the manufacture of phosphor-converted LEDs (pcLEDs) and while these components perform well, there are important opportunities for device performance improvement and manufacturing cost reductions. Among the materials systems commercially used in down converting and potentially also for up conversion with the most potential for price and performance improvement are certain rare earth phosphor formulations. Although SSL uses far less phosphor material than is used in legacy lighting products and are therefore less of a concern as a critical material, there are important performance improvements sought that are thought to lead to commercial manufacture of phosphor systems that are efficient yet more tolerant of operation at elevated temperatures for extremely long periods of time. Some new phosphors, such as those generally classified as Nitrides for example, are much more tolerant of operation at high temperatures and luminous flux but their manufacture and cost limits their wide spread use especially in certain high volume, first cost driven markets such as residential or "A-Line" lamp products. Also, there are important gaps in existing down-conversion spectrum in both color and efficiency especially at certain pump wavelengths. As a result, some pcLEDs are less comparable to more familiar continuous emission legacy lighting products such as those that follow black body radiation parameters. Up-converting phosphors or quantum-splitting phosphors also represent opportunities for pcLED device performance improvement but are today, not a practical addition in any known pcLED design. Even though the performance improvements possible with these approaches may be small, there may be opportunities to integrate these materials systems into existing or new phosphor systems or activators at minimal cost but with important performance or color quality improvements.

Questions – Contact: James R. Brodrick, james.brodrick@hq.doe.gov

b. Alternative Photonic Materials

Alternative color shifting solutions are presently under development that represents potential substitutes or replacements for traditional rare earth phosphor systems used in SSL products. The most popular alternatives are Quantum Dots (QDs) and Nano-Phosphors (NP). While still very nascent, there exist many technical aspects of how these systems might be used effectively as a viable high efficiency, long-lived alternative to conventional phosphors. For example, in comparison to commercial phosphor systems QDs are less efficient and experience a variety of non-radiative loss mechanisms. The loss mechanisms are not fully understood but any reduction of the non-radiative losses in these materials will improve their

efficiency and potentially, service life at elevated flux density and temperature. Development of a better understanding of non-radiative losses and other fundamental phenomena could lead to new materials and alloys that could be used to dramatically improve the performance of these structures by increasing the device conversion efficiency, lifetime or possibly emission line width. Similarly, out coupling efficiency and beam management can be effected by NPs or other structures resulting in improved optical performance. These additions may interact favorably with other components in the LED or OLED design architecture in such a way as to provide longer, more temperature tolerant performance at affordable incremental cost.

Questions – Contact: James R. Brodrick, james.brodrick@hq.doe.gov

c. Emitter Materials

The state-of-the-art emitter materials systems for both LEDs and OLEDs have become somewhat standardized especially in the extensively researched and mass-produced III-Nitride alloys. Even though these systems can be used today to manufacture economical, energy efficient lighting products, there remains ample room for fundamental materials improvement. In LED systems for example, a number of technical challenges such as droop and materials defects that arise as a consequence of the lattice constant mismatch between the emitter film and the substrate that it is deposited on. These conspire to limit device efficiency, lifetime and yield. In OLED systems, stable, long-life blue emitters, effects of compositional impurities, environmental contamination, current introduction and electrode transparency still remain as fundamental materials challenges that limit achievement of maximum efficacy, extraordinary lifetime and low cost of manufacture. Improvements in our understanding of these and similar fundamental effects may lead to the development of new materials that would further improve and advance market share of these important lighting technologies well beyond today's present levels.

The intent of this topic is to encourage innovative material science development or composite solutions that will enable SSL products to perform at their theoretically predicted maxima in the long run and meet or exceed the aggressive device performance goals established by the DOE in the SSL Multi-Year Program Plan (MYPP) available for download at http://www1.eere.energy.gov/buildings/ssl/. Responsive proposals must succinctly address one or more of the key R&D challenges described fully in the SSL MYPP. Innovations that address manufacturing technology and cost of LEDs while simultaneously addressing the fundamental materials challenges such as those described here as they pertain to general illumination applications are especially welcome. The key metric for judging responsiveness of all proposals however, will be commercialization potential and the prospect of making a lasting and positive impact on the rapidly evolving SSL industry resulting in better quality LEDs at reduced cost. Proposals that include technical risk are encouraged provided they articulate a viable plan to retire such risk during the Phase I period of performance with appropriate proof of principle demonstration. Projects that result in important intellectual property are especially valuable as they may provide future revenue in the form of royalties or cross-licenses to the benefit small business or participating technology transfer office.

Questions – Contact: James R. Brodrick, james.brodrick@hq.doe.gov

d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: James R. Brodrick, james.brodrick@hq.doe.gov

References:

1. 2015, U.S. Department of Energy, *Solid-State Lighting Research & Development Multi-Year Program Plan*, Prepared for Lighting Research and Development Building Technologies Program at the Department of Energy. (http://energy.gov/eere/ssl/downloads/solid-state-lighting-rd-plan)

2. 2014, U.S. Department of Energy, *Solid-State Lighting Program Overview*, Modest Investments, Extraordinary Impacts. (http://energy.gov/eere/ssl/downloads/solid-state-lighting-program-overview-brochure)

3. 2014, U.S. Department of Energy, *DOE Joint Solid-State Lighting Roundtables on Science Challenges*, Office of Energy Efficiency and Renewable Energy, (http://energy.gov/eere/ssl/downloads/doe-joint-solid-state-lighting-roundtables-science-challenges)

8. INSTRUMENTATION FOR ADVANCED CHEMICAL IMAGING

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

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

Grant applications are sought in the following subtopics:

a. High Spatial Resolution Ultrafast Spectroscopy

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

Questions – Contact: Larry Rahn, larry.rahn@science.doe.gov

b. Time-Resolved Chemical Information from Hybrid Probe Microscopies

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

Questions – Contact: Larry Rahn, larry.rahn@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Larry Rahn, larry.rahn@science.doe.gov

References:

1. Basic research for chemical imaging. BES Chemical Imaging Research Solicitation. (FY 2006). (http://science.energy.gov/~/media/grants/pdf/foas/2005/DE-FG01-05ER05-30.pdf).

2. Visualizing Chemistry, The progress and Promise of Advanced Chemical Imaging, National Academies Press. 2006. (http://www.nap.edu/catalog.php?record_id=11663).

9. SOFTWARE INFRASTRUCTURE FOR WEB-ENABLED CHEMICAL-PHYSICS SIMULATIONS

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The Office of Basic Energy Sciences (BES), within the DOE's Office of Science, seeks to advance the standards for predictive computational modeling in chemical physics, which is a key for research conducted by researchers in universities, laboratories and industry.

Grant applications are sought in the following subtopics:

a. Webware and Depot for Chemical-Physics Simulations and Data

The Department of Energy seeks to speed delivery of new material- and molecular systems for clean energy by enabling prediction of functionalities and processes of such systems prior to synthesis. Such computational predictive capabilities are also of importance to atomic and molecular physics, chemistry and chemical biology, coherent control of chemical reactions, materials sciences, magnetic- and electric

field phenomena, optics, and laser engineering. Recent advances in theory, algorithms, and hardware in materials and chemical sciences are yet to be widely available to the majority of scientifically and technically capable communities in the United States, especially those in the commercial sector. This topic seeks to reverse this situation and contribute to one goal of the Materials Genome Initiative which includes enhancing the rate of breakthroughs in complex materials chemistry and materials design. Creation of national web-enabled infrastructure for predictive theory and modeling is needed to facilitate the coordination and sharing of information and data, scalable codes, and for their implementation on or transfer to new architectures. In addition, a web-based infrastructure is needed to impose universal standards for data inputs and outputs in the multitude of codes and methodologies or to capitalize upon semantic strategies for bypassing the need for universal standards altogether. Industrial needs that are dependent on rapid insertion of capabilities developed by basic energy scientists include:

- Commercially viable transitioning and/or sustainably availing of validated computational approaches that span vast differences in time and length scales.

- Commercially viable transitioning and/or sustainably availing of robust and sustainable computational infrastructure, including software and applications for chemical modeling and simulation.

Resulting infrastructure should provide economically feasible means that allow networks consisting of specialized simulation groups to be linked with researchers in academia, industry, and government.

Grant applications are sought to develop and improve web-based tools for access to predictive theory and modeling.

Questions – Contact: Mark Pederson, mark.pederson@science.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Mark Pederson, mark.pederson@science.doe.gov

References:

1. 2011, Materials Genome Initiative for Global Competitiveness. National Science and Technology Council. (www.whitehouse.gov/sites/default/files/microsites/ostp/materials_genome_initiative-final.pdf)

2. Galli, G., and Dunning, T., 2009, U.S. Department of Energy, Discovery in Basic Energy Sciences: The Role of Computing at the Extreme Scale, Scientific Grand Challenges. (http://science.energy.gov/~/media/ascr/pdf/program-documents/docs/BES_exascale_report.pdf)

3. Crabtree, G., Glotzer, S., McCurdy, B., 2010, Computational Materials Sciences and Chemistry: Accelerating Discovery and Innovation through Simulation-Based Engineering and Science. Report of the Department of Energy Workshop. (http://science.energy.gov/~/media/bes/pdf/reports/files/cmsc_rpt.pdf)

4. 2011, U.S. Department of Energy, A Workshop to Identify Research Needs and Impacts in Predictive Simulation of Internal Combustion Engines (PreSICE), Sponsored by the Office of Basic Energy Sciences, Office of Science and the Vehicle Technologies Program, Office of Energy Efficiency and Renewable Energy. (http://science.energy.gov/~/media/bes/pdf/reports/files/PreSICE_rpt.pdf)

5. 2010, U.S Department of Energy, Basic Research Needs for Carbon Capture: Beyond 2020, Report based on SC/FE Workshop. (http://science.energy.gov/~/media/bes/pdf/reports/files/CCB2020_rpt.pdf)

6. 2005, U.S. Department of Energy, Opportunities for Discovery: Theory and Computation in Basic Energy Sciences, Report based on BESAC Deliberations. (http://science.energy.gov/bes/news-and-resources/reports/abstracts/#OD)

10. ADVANCED NUCLEAR ENERGY SYSTEMS RESEARCH

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The Office of Basic Energy Sciences (BES), within the DOE's Office of Science, seeks to advance actinide and fission-product separations that support the DOE missions in energy, environment, and national security [1-2]. Proposed research and development (R&D) must focus on radioactive materials. Applications proposing R&D work only with stable materials or surrogates will be considered non-responsive.

Grant applications are sought in the following subtopics:

a. Enhanced Chemical Separation Capabilities for the Actinides

More efficient and environmentally friendly processes and separations chemistry for the purification of the actinides for nuclear fuel cycles, for metal production, and at the ultra-microscale for nuclear forensics and other applications are greatly needed. Many of our current chemical processes were developed more than sixty years ago and suffer from inefficiency. For the anticipated large expansion in the use of nuclear power to be realized, the risk of nuclear weapons proliferation from nuclear-energy operations must be minimized, and an inexpensive, publicly acceptable pathway to deal with the used nuclear fuel must be established that will necessitate separation of waste constituents.

Questions – contact: Philip Wilk, philip.wilk@science.doe.gov

b. Technetium Characterization, Removal, and Disposition

Among radioactive constituents present in waste, technetium (Tc) presents a unique challenge with its long half-life, complex chemical behavior, and mobility in the subsurface environment; therefore presenting a persistent concern. Its volatility makes incorporation into a durable waste form a challenge for nuclear waste management. Retrieval from existing waste tanks, potential separation, and immobilization must address multiple chemical species and their behavior. The technical challenges associated with Tc can be divided into three main areas: 1) Tc characterization, including understanding

inventory, speciation, distribution, detection and quantification methods; 2) Tc separation/removal from process streams; and 3) Tc disposition, including behavior in waste forms (glass, grout, etc).

Questions – Contact: Philip Wilk, philip.wilk@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Philip Wilk, philip.wilk@science.doe.gov

References:

1. 2006, Office of Basic Energy Sciences, U.S. Department of Energy, *Basic Research Needs for Advanced Nuclear Energy Systems,* Report of the Basic Energy Sciences Workshop. (http://science.energy.gov/~/media/bes/pdf/reports/files/anes_rpt.pdf)

2. 2010, Office of Basic Energy Sciences, U.S. Department of Energy, *Science for Energy Technology: Strengthening the Link between Basic Research and Industry*, Report of a subcommittee to the Basic Energy Sciences Advisory Committee. (http://science.energy.gov/bes/news-and-resources/reports/)

11. HYDROGEN AND HIGHER HYDROCARBONS FROM ORGANIC WASTE STREAMS

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

Organic waste streams, including, but not limited to, food and beverage wastewaters, municipal wastewater, livestock manure slurries, the non-recyclable fraction of municipal solid waste, and biogas produced from any of the above, contain substantial amounts of chemical energy. Since these resource streams are biogenic in origin, energy produced from them can be considered renewable, as the U.S. Environmental Protection Agency has done in granting eligibility to fuels produced from these sources for cellulosic Renewable Identification Numbers.[1] While some of the available energy is currently being captured, a significant amount remains untapped.[2-4] The potential to produce fuels and power from waste streams has gained interest in recent years, including concepts, such as “energy-positive water resource recovery” facilities, which produce clean water, energy, and nutrients from municipal wastewater[5]; Integrated Biorefineries[6]; and Combined Heat, Hydrogen, and Power fuel cell projects.[7] Certain families of biologically-based technologies have the potential to improve the economic viability of energy recovery from these resource streams. These technologies, such as microbial electrochemical technologies (MxCs) (e.g., microbial fuel cells and microbial electrolysis cells) or anaerobic membrane bioreactors, offer significant potential not only to reduce or eliminate current wastewater treatment steps that require large energy inputs, but also to produce readily usable fuels and product precursors.

While specifics will vary by subtopic, the following criteria will apply to all applications:

- Proposed systems must utilize organic waste streams as the primary feedstock to produce fuels. Wet waste streams are defined in the Bioenergy Technologies Office Multi-Year Program Plan.[8] For purposes of this Small Business Innovation Research topic, biogas is included within the definition of organic waste streams.
- Applications should identify potential commercial applications and relevant waste streams. By Phase II, and preferably within Phase I, proposed projects should employ actual (rather than model or synthetic) waste streams as feedstocks. Partnerships with relevant suppliers/sources of environmental/civil engineering expertise are highly encouraged.
- Successful applications will propose to develop and run pilot systems by the end of Phase II, at a relevant scale (e.g., 100–1,000 L reactor volume).
- Applications must address the energy efficiency of the system. Successful applications will minimize the ratio of required energy inputs to the energy potential of proposed outputs. Lower Heating Value is one possible measure, but applicants may propose other metrics.
- Projects that contribute to and/or leverage the development of fundamental scientific knowledge in areas, including, but not limited to, interspecies electron transfer, improved understanding of heterogeneous biological communities, and advances in toolkit development in terms of proteomics, metabolomics, transcriptomics, and other related areas are of particular interest.
- Higher hydrocarbons are generally defined as including at least three carbon molecules. However, novel approaches for the production of syngas from eligible feedstocks may be considered, particularly if the application includes conversion of the syngas to a higher hydrocarbon. Proposals that produce ethanol or methanol as a final product will be considered non-responsive, although both of those substances are acceptable as process intermediates.

Grant applications are sought in the following subtopics:

a. Production of Hydrogen and Electricity from Organic Waste Streams

In this subtopic, the U.S. Department of Energy is seeking novel research and development (R&D) to develop MxCs (e.g., microbial fuel cells and microbial electrolysis cells) that can produce hydrogen or electricity from waste streams. MxCs have shown promise at the bench scale in producing electricity, hydrogen, and higher hydrocarbons, but challenges remain for commercial applications.[9-11] The systems should either clean wastewaters or reduce the disposal requirements of other waste feedstocks.

Applications should propose R&D that addresses barriers to the commercial application of MxCs; a number of barriers and R&D needs were identified in the 2013 Biological Hydrogen Production Workshop Summary Report,[12] and discussed in the presentations of the recent Hydrogen, Hydrocarbons, and Bioproduct Precursors from Wastewaters Workshop.[13] The proposed systems should be capable of either producing at least 4 $L/L_{reactor}$/day hydrogen, or generating excess electricity after taking into account required system energy inputs (e.g., pumping requirements).

Questions – Contact: Katie Randolph, katie.randolph@ee.doe.gov

b. Production of Higher Hydrocarbons from Organic Waste Streams

The U.S. Department of Energy's Bioenergy Technologies Office is interested in harnessing biological pathways to produce biofuel and bioproduct precursors from wet organic waste streams as enumerated in the first sentence above. Proposals that utilize algae, even if grown on wastewater, and dry waste streams,

such as corn stover, will be considered non-responsive. Within the targeted domains, the following several pathways are possible:

a. Arresting the methanogenesis stage in anaerobic digestion in order to produce higher-value biofuel and bioproduct precursors
b. Employing biological mechanisms to utilize both the CO_2 and methane from biogas in the production of higher-value products
c. Exploring applications of synthetic biology that allow for the introduction of high-value pathways into organisms relevant to industrial scale production
d. Investigating phylogenetic families other than bacteria.

Carbon efficiency is a primary consideration. Applications will be evaluated on their probability of maximizing utilization of the biogenic carbon available in relevant resource streams.

In all cases, the Bioenergy Technologies Office is interested in projects that present the possibility of producing commercially relevant and economically competitive higher hydrocarbons from biogenic sources as a replacement for petroleum. Examples include, but are not limited to, butanol, 1,4-butanediol, and long-chain fatty acids, such as succinic, muconic, and lactic acids.

Questions – Contact: Dan Fishman, daniel.fishman@ee.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Dan Fishman, daniel.fishman@ee.doe.gov

References: Subtopic a:

1. 2013, Lovley, D.R., and Nevin, K.P., Electrobiocommodities: Powering Microbial Production of Fuels and Commodity Chemicals from Carbon Dioxide with Electricity, *Current Opinion in Biotechnology*, Vol. 24, Issue 3, pp. 385–390. (http://www.sciencedirect.com/science/article/pii/S0958166913000268)

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References:

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3. 2014, U.S. Department of Agriculture, *Biogas Opportunities Roadmap*, Voluntary Actions to Reduce Methane Emissions and Increase Energy Independence, p. 28. (http://www.epa.gov/climatechange/Downloads/Biogas-Roadmap.pdf)

4. Tarallo, S., ENV-SP, Black, Veatch, 2014, (WERF) Water Environment Research Federation, *Utilities of the Future Energy Findings*, Final Report, ENER6C13. (https://www.americanbiogascouncil.org/pdf/waterUtilitiesOfTheFuture.pdf)

5. 2012, Water Environment Federation (WEF), *Energy Roadmap Version 1.0*, Driving Water and Wastewater Utilities to More Sustainable Energy Management. (http://news.wef.org/wef-energy-roadmap-serves-as-user-guide-for-utilities-of-all-sizes/)

6. 2015, U.S. Department of Energy, *Integrated Biorefineries*. (http://www.energy.gov/eere/bioenergy/integrated-biorefineries)

7. 2013, U.S. Department of Energy, *Tri-Generation Success Story: World's First Tri-Gen Energy Station—Fountain Valley*. (http://energy.gov/eere/fuelcells/downloads/tri-generation-success-story-worlds-first-tri-gen-energy-station-fountain)

8. 2015, U.S. Department of Energy, Bioenergy Technologies Office*, Multi-Year Program Plan: March 2015,* p. 244. (http://www.energy.gov/eere/bioenergy/downloads/bioenergy-technologies-office-multi-year-program-plan-march-2015-update)

12. MEMBRANES AND MATERIALS FOR ENERGY EFFICIENCY

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

Separation technologies recover, isolate, and purify products in virtually every industrial process. Using membranes rather than conventional energy intensive technologies for separations could dramatically reduce energy use and costs in key industrial processes [1]. Separation processes represent 40 to 70 percent of both capital and operating costs in industry. They also account for 45 percent of all the process energy used by the chemical and petroleum refining industries every year. In response the Department of Energy supports the development of high-risk, innovative membrane separation technologies and related materials. Many challenges must be overcome before membrane technology becomes more widely adopted. Technical barriers include fouling, instability, low flux, low separation factors, and poor durability. Advancements are needed that will lead to new generations of organic, inorganic, and ceramic membranes. These membranes require greater thermal and chemical stability, greater reliability, improved fouling and corrosion resistance, and higher selectivity leading to better performance in existing industrial applications, as well as opportunities for new applications. Materials for energy efficiency include both organic and inorganic types. Their applications can be for supporting structures, such as durable sealing materials to increase reliability of hydrogen storage or for electronics substrates. They also include materials that are key to highly pure hydrogen. Finally, conductor materials that promise 50% or more improvement in energy efficiency are examined.

Grant applications are sought in the following subtopics:

a. High Selectivity Membranes

This subtopic is focused on the advancement of manufacturing processes that are able to produce membranes with exceptional selectivity for separations.

High performance membranes offer the potential to provide game-changing process energy advances. Specifically we are interested in chemical separations, desalination, and gas separations. Of greatest interest are methods that employ strong, thin membranes (e.g., covalently bonded, one-molecule-thick structures) for high permeance, with atomically precise pores for high selectivity. In desalination, a rate increase of 2-3 orders of magnitude over reverse osmosis is projected for a system with not only controlled pore size but also engineered pore edge composition [1]. In principle, a series of membranes of sufficient selectivity could separate air into its raw components of N2, O2, Ar, CO2, Ne, He, etc. for significant energy savings in a wide range of chemical and combustion processes [2, 3], and for greenhouse gas reduction.

We seek grant applications to advance scalable technologies that provide order-of-magnitude increments over the performance of current industrial separation processes. The focus of the application must be on significant improvements in uniformity of pore size distribution and composition for near 100% selectivity. Consideration should be given to addressing the other barriers cited in this topic: fouling, instability, flux, durability, and cost. The choice of membrane material should be appropriate to the target separation in a commercial setting. Target separations with high energy impact are preferred. As a deliverable, a minimum of 50% energy savings over separations in current commercial practice shall be demonstrated through the manufacture of exemplar parts or materials, with sufficient experimental measurements and supporting calculations to show that cost-competitive energy savings can be achieved with practical economies of scale. The application should provide a path to scale up in potential Phase II follow on work.

Questions – Contact: David Forrest, david.forrest@hq.doe.gov

b. High Performance Conductors

This subtopic is focused on methods to enhance the thermal and electrical conductivity of commercial metals.

Electrical and thermal conductivity are thermophysical properties of metals that play key roles in the energy efficiency in many applications. In general, we seek to increase both properties but are limited by competing material requirements such as strength and oxidation resistance. High electrical conductivity, strong aluminum would address transmission losses (0.2-0.4 quads) and reduce total ownership costs in high voltage power transmission lines. High electrical conductivity aluminum could replace copper for wiring and motor lightweighting in certain aircraft and automotive systems. High conductivity copper could improve the efficiency of electric motors and reduce the weight of aircraft and automobiles. Improving the thermal conductivity of steels and superalloys would improve the efficiency of high temperature processes (including power generation) through high performance heat exchangers, and would reduce material requirements.

There are several new approaches, which have seen mixed degrees of technical success but no significant commercial inroads due to cost or scalability: multifunctional metal/polymer composites, nanocarbon infusion processes, severe plastic deformation of aluminum, and metal matrix composites. Specific challenges include establishing a quality interface between the metal and high conductivity material (such as carbon nanotubes) in metal matrix composites, and minimizing defects that reduce conductivity in the highly conductive material [1-4].

We seek grant applications to advance scalable technologies that provide at least a 50% increment over the performance of commercial metal conductors. The improvement can be in electrical conductivity or thermal conductivity either on a volumetric or weight basis. The choice of metallurgical system should be appropriate to the target component in a commercial setting. Consideration should be given to addressing all aspects of the materials design at the system level (cost, corrosion and oxidation resistance, joining and fabrication procedures, strength, fatigue, hardness, ductility). Industrial uses of the enhanced conductors that will result in high energy impact are preferred. As a deliverable, a minimum of 50% energy savings in service over current commercial practice shall be demonstrated through the manufacture of exemplar components or materials, with sufficient experimental measurements and supporting calculations to show that cost-competitive energy savings can be achieved with practical economies of scale. The application should provide a path to scale up in potential Phase II follow on work.

Questions – Contact: David Forrest, david.forrest@hq.doe.gov

c. Fuel Cell Membranes

Polymer electrolyte membrane (PEM) fuel cells are a leading candidate to power zero emission vehicles, with several major automakers already in the early stages of commercializing fuel cell vehicles powered by PEM fuel cells. PEM fuel cells are also of interest for stationary power applications, including primary power, backup power, and combined heat and power. Commercial PEM technology typically is based on perfluorosulfonic acid ionomers, but these ionomer materials are expensive, particularly at the low volumes that will be needed for initial commercialization. Non-PFSA PEMs, including those based on

hydrocarbon membranes, represent a lower-cost alternative, but relatively low performance and durability has limited non-PFSA PEM applications to date.

Development of novel hydrocarbon ionomers and PEMs suitable for application in PEM fuel cells is solicited through this subtopic. Novel PEMs developed through this subtopic should have properties and characteristics required for application in PEM fuel cells, including:

- High proton conductivity in a range of temperature and humidity conditions
- Good film forming properties enabling formation of thin (<10 µm) uniform membranes
- Low swelling and low solubility in liquid water
- Low creep under a range of stress, temperature, and humidity conditions
- Low permeability to gases including H_2, O_2, and N_2
- Chemical and mechanical durability sufficient to pass the accelerated stress tests in the Fuel Cell Tech Team Roadmap [1]

The goal of any proposed work under this subtopic should be to produce a PEM that can meet all of the technical targets in the table below. PEM technology proposed for this subtopic should be based on proton-conducting non-perfluorinated ionomers, but may include reinforcements or other additives. Membrane samples should be tested at an independent laboratory at the end of each phase. Phase 1 should include measurement of chemical and physical properties to demonstrate feasibility of meeting the targets below related to these parameters, while Phase 2 addresses long term durability and development of manufacturing processes to meet the cost targets.

Technical Targets: Fuel Cell Membranes for Transportation Applications [2]

Characteristic	Units	Target 2020
Maximum operating temperature	°C	120
Area specific proton resistance at:		
Maximum operating temp and water partial pressures from 40 to 80 kPa	Ohm cm^2	≤ 0.02
80°C and water partial pressures from 25 - 45 kPa	Ohm cm^2	≤ 0.02
30°C and water partial pressures up to 4 kPa	Ohm cm^2	≤ 0.03
-20°C	Ohm cm^2	≤ 0.2
Maximum Oxygen cross-over	mA / cm^2	2
Maximum Hydrogen cross-over	mA / cm^2	2
Minimum electrical resistance	ohm cm^2	1000
Cost	$ / m^2	≤ 20
Durability		
Mechanical	Cycles w/ < 2 mA/cm^2 crossover	≥ 20,000
Chemical	Hours	> 500

Questions – Contact: Donna Ho, Donna.Ho@ee.doe.gov, or Dimitrios Papageorgopoulos, Dimitrios.Papageorgopoulos@ee.doe.gov

d. Other

In addition to the specific subtopics listed above, the Department solicits applications in other areas that fall within the specific scope of the topic description above.

Questions – Contact: David Forrest, david.forrest@hq.doe.gov

References: Subtopic a:

1. Cohen-Tanugi, D., and Grossman, J.C., 2012, Water Desalination Across Nanoporous Graphene, *Nano Letters*, Vol. 12, Issue 7, pp. 3602-3608. (http://pubs.acs.org/doi/abs/10.1021/nl3012853)

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3. Kurunov, I.E., and Beresneva, M.P., 1999, Effect of Enriching the Blast with Oxygen on the Production Cost of Pig Iron, *Metallurgist*, Vol. 43, Issue 5, pp.217-220. (http://link.springer.com/article/10.1007%2FBF02466966)

References: Subtopic b:

1. Chai, G., Sun, Y., Sun, J., et al., 2008, Mechanical properties of carbon nanotube copper nanocomposites, Journal of Micromechanics and Microengineering, Volume 18, No. 3. (http://iopscience.iop.org/0960-1317/18/3/035013)

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3. Uddin, S.M., et al., 2010, Effect of Size and Shape of Metal Particles to Improve Hardness and Electrical Properties of Carbon Nanotube Reinforced Copper and Copper Alloy Composites, *Composites Science and Technology*, Vol. 70, pp. 2253–2257 (http://www.researchgate.net/publication/229107747_Effect_of_size_and_shape_of_metal_particles_to_improve_hardness_and_electrical_properties_of_carbon_nanotube_reinforced_copper_and_copper_alloy_composites)

4. Liu Z.Y., et al., 2014, Tensile Strength and Electrical Conductivity of Carbon Nanotube Reinforced Aluminum Matrix Composites Fabricated by Powder Metallurgy Combined with Friction Stir Processing, *Journal of Materials Science & Technology*, Vol. 30, Issue 7. Pp. 649-655. (http://www.sciencedirect.com/science/article/pii/S1005030214000747)

References: Subtopic c:

1. 2013, *Fuel Cell Technical Team Roadmap*, USDRIVE, Driving research and Innovation for Vehicle Efficiency and Energy Sustainability. (http://energy.gov/sites/prod/files/2014/02/f8/fctt_roadmap_june2013.pdf)

2. 2012, Fuel Cell Technologies Office, Technical Plan- Fuel Cells, *Multi-Year Research, Development and Demonstration Plan*, Section 3.4. (http://energy.gov/sites/prod/files/2014/12/f19/fcto_myrdd_fuel_cells.pdf)

13. SUBSURFACE TECHNOLOGY AND ENGINEERING RESEARCH AND DEVELOPMENT

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

The Office of Basic Energy Sciences (BES), in support of the DOE Office of the Under Secretary for Science and Energy's Subsurface Technology and Engineering Research, Development and Demonstration (SubTER) Crosscut Initiative, seeks to advance the state of the art in adaptive control or "mastery" of the subsurface for energy production and storage and for the management of energy waste streams.

While subsurface sources constitute the Nation's primary source of energy (providing more than 80 percent of total U.S. energy needs today), they are also critical to the Nation's low-carbon and secure energy future. Next generation advances in subsurface technologies will enable access to more than 100 gigawatt-electric (GWe) of clean, renewable geothermal energy, as well as safer development of domestic natural gas supplies. The subsurface provides hundreds of years of safe storage capacity for carbon dioxide (CO_2) and opportunities for environmentally responsible management and disposal of hazardous materials and other energy waste streams. The subsurface can also serve as a reservoir for energy storage for power produced from intermittent generation sources, such as wind and solar. These opportunities are directly linked to Administration priorities and to broader societal needs. Clean energy deployment and CO_2 storage are critical components of the President's Climate Action Plan and are necessary to meet the 2050 greenhouse gas (GHG) emissions reduction target of 83 percent below 2005 levels. Increasing domestic hydrocarbon resource recovery in a sustainable and environmentally sound manner is also an Administration goal that enhances national security and fuels economic growth. Thus, discovering and effectively harnessing subsurface resources while mitigating impacts of their development and use are critical pieces of the Nation's energy strategy moving forward. Mastery of the subsurface requires efforts to address the following key challenges to optimize energy production, energy/CO_2 storage, and waste storage/disposal:

- *Discovering, characterizing, and predicting*: Efficiently and accurately locating target subsurface geologic environments; quantitatively inferring their evolution under future engineered conditions; and characterizing the subsurface at a relevant scale;
- *Accessing*: Safe and cost-effective drilling or mining with properly managed reservoir integrity;
- *Engineering*: Creating the desired conditions in challenging high-pressure/high-temperature environments;
- *Sustaining*: Maintaining these conditions over long time frames throughout complex system evolution; and
- *Monitoring*: Improving observational methods and advancing understanding of the microscopic basis of macroscopic complexity throughout system lifetimes.

Grant applications are sought in the following subtopics:

a. Innovative Measurement of New Subsurface Signals Including Stress

Grant applications are sought to research, develop, and deploy new and original processes, techniques, tools, and/or sensors that support the SubTER crosscut initiative's thrust areas of:

1. Subsurface Stress: technologies that measure the state of stress in the subsurface, and
2. New Subsurface Signals: deployable sensors and new methods of integrating different data types to interrogate the subsurface.

Responsive applications to this subtopic could include tools to image fracture networks, ways to improve visualization of the subsurface, and sensing and/or monitoring tools of all kinds, including fiber optic based technologies. The innovations sought range from those that address grand challenges, such as measuring in situ stress real time, to more incremental advancements, such as addressing hydrogen darkening of optical fibers in wells.

Questions – Contact: Josh Mengers, Joshua.Mengers@hq.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department solicits applications in other areas that fall within the specific scope of the topic description above.

Questions – Contact: Josh Mengers, Joshua.Mengers@hq.doe.gov

References:

1. 2014, U.S. Department of Energy, *Subsurface Control for a Safe and Effective Energy Future*, SubTER Crosscut White Paper. (http://energy.gov/downloads/subter-crosscut-white-paper)

2. 2014, The MITRE Corporation, *Subsurface Characterization Letter Report*, SubTER Jason Report, JSR-14-Task-013. (http://www.energy.gov/downloads/subter-jason-report)

14. ADVANCED FOSSIL ENERGY TECHNOLOGY RESEARCH

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from hydrocarbon fuels. Advanced Fossil Energy technologies must allow the Nation to use its indigenous fossil energy resources more wisely, cleanly, and efficiently. These include R&D activities required to reduce the capital and operating cost and to meet zero emission targets in power systems (e.g., turbines, fuel cells, hybrids, novel power generation cycles), coal conversion (e.g., gasification) and beneficiation, advanced combustion (e.g., oxy-combustion, chemical looping, ultra super critical steam), hydrogen and fuels, and beneficial re-use of CO_2. This topic addresses grant applications for the development of innovative, cost-effective technologies for improving the efficiency and environmental performance of advanced large scale

industrial and utility fossil energy power generation and natural gas recovery systems. The topic serves as a bridge between basic science and the fabrication and testing of new technologies. Small scale applications, such as residential, commercial and transportation will not be considered. Generally, electrochemical (SOFC excepted), microwave and plasma processes will not be considered due to high energy requirements. Applications determined to be outside the mission or not mutually beneficial to the Fossil Energy and Basic Energy Sciences programs will not be considered.

Grant applications are sought in the following subtopics:

a. Shale Gas Conversion to Liquid Fuels and Chemicals

With the discovery of vast quantities of natural gas available in various shale gas formations in the U.S. comes the opportunity to convert this gas, traditionally used directly as fuel, into more value added products. Traditionally, petroleum has been used to make ethylene, propylene and other building blocks used in the production of a wide range of other chemicals. We need to develop innovative processes that can readily make these chemical intermediates from natural gas.

The methane fraction can be converted into intermediates such as ethylene via oxidative coupling or reforming to synthesis gas, whereas the ethane/propane fraction can be converted into ethylene via conventional steam pyrolysis. Since methane is rather inert and requires high temperatures to activate strong chemical bonds, practical and cost-effective conversion technologies are needed. Attempts to develop catalysts and catalytic processes that use oxygen to make ethylene, methanol, and other intermediates have had little success as oxygen is too reactive and tends to over-oxidize methane to common carbon dioxide. Recent advances with novel sulfide catalysts have more effectively converted methane to ethylene, a key intermediate for making chemicals, polymers, fuels and , ultimately products such as films, surfactants, detergents, antifreeze, textiles and others.

Proposals are sought to develop novel and advanced concepts for conversion of shale gas to chemicals based on advanced catalysts. Processes must have high selectivity and yield compared to existing state of the art. Proposals must be novel and innovative and show clear economic advantages over the existing state of the art.

Questions – Contact: Doug Archer, douglas.archer@hq.doe.gov

b. Additive Manufacturing for Solid Oxide Fuel Cell (SOFC) Components

Additive manufacturing (AM) which is used to create components in a layering manner to achieve intricate final shape products has been identified as a potentially attractive option for the manufacture of high temperature performance components used in SOFC technology in order to address the need for components processing that not only maintains structural integrity but also offers the ability to perform multiple functions as well. AM also enables the design and synthesis of materials whose microstructure and properties allow for the construction of such components. Due to the limitations in terms of spatial control and high reproducibility of microstructures involving traditional screen printing, slurry pasting, and dip coating methods, there has been of late an increasing interest in inkjet printing and other direct-write additive processes.
Grant applications are sought for research and development to innovate AM techniques and to design and generate SOFC structures and components with functionality and characteristics that exceed the

performance requirements of state of the art materials and manufacturing processes. Approaches of interest include, but are not limited to additive manufacturing techniques to engineer preferred architectures or microstructure of a material system that possesses enhanced physical, electrical and thermal properties for high temperature SOFC applications. Techniques for SOFC interconnect coating and electrode infiltration are not of interest. A complete description of the manufacturing process required to achieve the proposed architectures should be provided to facilitate analysis of potential cost entitlements and implementation complexity. Applications can focus on individual components; however, a clear plan must be presented that outlines how entire SOFC cell or stack architectures would be fabricated, implemented, and perform.

Questions – Contact: Patcharin Burke, patcharin.burke@netl.doe.gov

c. CO_2 Capture from Low Concentration Sources

DOE has a large program associated with capture carbon from higher concentration CO_2 sources including both coal combustion and coal gasification units. However, there are other sources associated with coal power systems, resource recovery, and emissions mitigation where the concentration of the CO_2 is smaller but collectively these can represent a large quantity of CO_2 emissions.
In response to the environmental concerns and prevailing market conditions facing the coal industry, the DOE is seeking technologies to address CO_2 capture from coal-related sources producing low concentration CO_2 emissions. Some technologies (materials and processes) may have inherent advantages when capturing CO2 at these lower concentrations.

Grant applications are sought for cost-effective CO_2 capture technologies that mitigate CO_2 from coal-relevant gases with CO_2 concentrations of <1 vol% and also highlight the size and relevance of the targeted low concentration market. The objective is to initiate R&D of applied cost-effective CO_2 capture solutions for low concentration (<1 vol%), coal-relevant CO_2 sources. Technology proposed in this topic area may include, but is not limited to: coal-relevant lifecycle GHG emissions such as those from mining operations; approaches that are part of hybrid CO_2 capture/conversion process and CO_2 "polishing" steps that address the lower concentrations of residual CO_2 resulting from less than 100% capture. Applicants that have already identified a low CO_2 concentration market and successfully completed proof-of-concept analytical studies and simulations showing a pathway towards the aggressive Fossil Energy performance goals either as part of earlier DOE or non-DOE supported efforts should apply.

Questions – Contact: John Litynski, john.litynski@hq.doe.gov

d. Modifications to Existing Alloys that Promote Corrosion and / or Erosion Resistance in Supercritical Carbon Dioxide Based Power Cycle Applications

There has been an increase in interest over the past several years in supercritical carbon dioxide (sCO_2) cycles for power generation. These cycles offer the potential for increased efficiency over Rankine cycles with inherent capture of carbon dioxide using oxy-fuel combustion of natural gas or coal derived syngas as the heat source. The application of sCO_2 cycles to commercial power generation necessitates the development of new technologies in several areas, especially materials that are used in high pressure and temperature conditions under which sCO_2 based power cycle applications operate. The severe conditions occurring at both high pressures and temperatures up to 20-25 MPa and 550-700° C and higher, respectively can impose high levels of stress and severe challenges to the integrity of materials that are

used in the sCO_2 system, especially in terms of corrosion and erosion resistance. Although many superalloys that are classified into three main categories based on their major compositional element (nickel-, iron-nickel-, and cobalt-base alloys) are generally considered to be thermally stable at temperatures below 1500°C, little is known about material compatibility with CO_2 under supercritical conditions.

Grant applications are sought for research and development to understand and develop corrosion and erosion resistance of sCO_2 candidate materials in order to prevent unexpected deterioration of components or decline in efficiency. Approaches of interest include, but are not limited to investigations of:

1) the effects of protective or non-protective oxide layers induced from additive alloying elements on corrosion and erosion resistance of candidate materials and the corresponding dependence on temperature and pressure at a range of operating conditions.
2) the kinetics of oxide growth in an effort to build accurate models of corrosion mechanisms in materials used in sCO_2 applications in order to predict corrosion and service life of alloys under relevant operational conditions.

Questions – Contact: Seth Lawson, seth.lawson@netl.doe.gov

e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Doug Archer, douglas.archer@hq.doe.gov

References: Subtopic a:

1. Zhu, Q., Wegener, S.L., Xie, C., et al., 2013, Sulfur as a Selective 'Soft' Oxidant for Catalytic Methane Conversion Probed by Experiment and Theory, *Nature Chemistry*, Vol. 5, Issue 2, pp. 104-109. (http://www.ncbi.nlm.nih.gov/pubmed/23344430).

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1. P. Khatri-Chhetri, A. Datar, and D. Cormier "Novel SOFC Processing Techniques Employing Printed Materials," Advances in Materials Science for Environmental and Energy Technologies: Ceramic Transactions, Volume 236, 129-139. (http://onlinelibrary.wiley.com/doi/10.1002/9781118511435.ch14/summary)

References: Subtopic c:

1. 2013, U.S. Department of Energy, Office of Fossil Energy, *Carbon Capture Technology Program Plan*, Clean Coal Research Program. (http://www.netl.doe.gov/File%20Library/Research/Coal/carbon%20capture/Program-Plan-Carbon-Capture-2013.pdf

References: Subtopic d:

1. Nguyen, T.D., Zhang, J., and Young, D.J., Water Vapor Effects on Corrosion of Fe-Cr and Fe-Cr-Ni Alloys Containing Silicon in CO2 Gas at 818C, *Oxidation of Metals*, Vol. 83, Issue 5-6, pp. 575-594. (http://link.springer.com/article/10.1007%2Fs11085-015-9536-5)

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15. ADVANCED FOSSIL ENERGY SEPARATIONS AND ANALYSIS RESEARCH

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from hydrocarbon fuels. This topic addresses grant applications for the development of innovative, cost-effective technologies for improving the efficiency and environmental performance of advanced large scale industrial and utility fossil energy power systems and natural gas recovery systems. Areas considered include research

and technology issues and opportunities for carbon storage, including, geologic storage, monitoring, verification, and accounting, enhanced oil recovery and residual oil zone production using CO_2, advanced simulation and risk assessment, and CO_2 separation . In addition, efforts on enabling technology (e.g., sensors and controls) energy conversion, water issues, advanced modeling and simulation materials critical to the implementation and optimization of fossil power and recovery systems are included. The topic serves as a bridge between basic science and the fabrication and testing of new technologies. Small scale applications, such as residential, commercial and transportation will not be considered. Applications determined to be outside the mission and scope or not mutually beneficial to the Fossil Energy and Basic Energy Science programs will not be considered.

Grant applications are sought in the following subtopics:

a. Enabling Technologies for Advanced Combustion Systems

Develop and validate a predictive, multi-scale, combustion model to optimize the design and operation of a spouted bed using a coal and biomass mixture to reduce GHG emissions. This predictive capability, if attained, will change fundamentally the process for combustion of combined fuels by establishing a scientific understanding of sufficient depth and flexibility to facilitate realistic simulation of mixed fuel combustion in these newly proposed power boiler designs.

Similar understanding in aeronautics has produced the beautiful and efficient complex curves of modern aircraft wings. These designs could never have been realized through cut-and-try engineering, but rather rely on the prediction and optimization of complex air flows. An analogous experimentally validated, predictive capability for combustion is a daunting challenge.
This SBIR project should demonstrate and validate the design and operation of the spouting fluidized bed for use with coal and biomass fueled combustion and verifies how it compares with a conventional fluidized bed in terms of efficiency and reduces carbon in ash due to better control of residence time.

The scope of the project can comprise design, fabrication, and testing of a small demonstrable unit with pulverized coal and biomass as feedstock. Research will include collecting various data and information to address any major technical gaps. If successful in Phase 1 the project has a chance to move to Phase II where substantially higher funding is given.

Questions – Contact: Bhima Sastri, Bhima.Sastri@hq.doe.gov

b. Advanced Shale Gas Recovery Technologies for Horizontal Well Completion Optimization

Proposals are sought to develop and test technologies that will reduce the amount of water needed for hydraulic fracturing when completing natural gas wells or that will improve the apparent low (<30%) natural gas and liquids recovery efficiency currently associated with horizontal, hydraulically fractured wells producing from shale formations. Proposals should focus on addressing a number of important areas where cost effective improvements may be possible. The objective is to increase the efficiency of resource recovery on a per well basis or reduce the volume of fresh water required to produce a unit volume of natural gas. For example, research could include quantitative assessments of the practical and economic limits and potential benefits (if any) of employing mixtures of natural gas (not LPG as is currently practiced) with conventional sand-laden fracturing fluids, as a novel fracturing fluid to partially replace water in the

large volume, multiple stage hydraulic fracturing treatments representative of those being applied in shale gas and shale oil plays today.

Examples of analyses could include laboratory experiments and/or computer simulations that quantify the effect on relative permeability to gas in a producing wellbore when mixtures of conventional fracturing fluids and natural gas (versus fracturing liquids only) are employed as fracturing fluids under conditions representative of major shale gas plays. Research could characterize the potential volumes and rates of natural gas/conventional fracturing fluid mixtures required to achieve well productivity similar to that achieved when wells are fractured using conventional fracturing fluids alone.

Other examples of analysis could aim to characterize the suitability of the rheology of such conventional fracturing fluid/natural gas mixtures for large volume hydraulic fracturing, and to prove the feasibility of employing natural gas as a partial alternative to water, as justification for a Phase II field experiment focused on testing the process.

Questions – Contact: Al Yost, albert.yost@netl.doe.gov

c. CO_2 Use and Reuse

To reduce risk and offset the cost of CCS, development of CO_2 utilization/conversion technologies, specifically those that rely on biological processes (e.g., algae) or mineralization/carbonation processes to generate value-added products will be required. A larger and more diverse market is needed to facilitate deeper GHG reductions from CO_2 sales beyond what can be realized by Enhanced Oil Recovery (EOR) alone. For instance, a coal-fired power plant equipped with a CO_2 capture and purification unit could offer multiple gas streams with varying concentrations of CO_2 potentially suitable for CO_2 utilization/conversion, including: (1) flue gas exiting the desulfurization unit (prior to entering the downstream CO_2 capture and purification unit), (2) CO_2-dilute flue gas being directed to the stack following bulk CO_2 removal, and (3) concentrated CO_2 exiting the CO_2 capture and purification unit that is ready for compression and storage.

Grant applications are sought for the development or enhancement of novel technologies that support DOE's goals to reduce carbon emissions at a relative cost below $40 per tonne of CO_2. It is expected that the revenue generated from these novel utilization processes may result in positive revenue. The applicant must demonstrate a thorough understanding of the biological or chemical CO2 utilization/conversion process being proposed and its ability to integrate with coal-fired power plants. Of particular importance is a thorough discussion of the integration approach with the power plant, optimal inlet CO2 concentration, rate of CO2 utilization and practical limits on how much flue gas could be processed from a single power plant, associated CO2 emission reduction, process footprint, impact and ultimate fate of heavy metals and other flue gas impurities, novel dewatering concepts, knowledge gaps and key technical challenges, and process costs.

Preference will be given to applications that have the potential to be economically viable at large-scale based on the value of the products produced, considering the existing market for these products. Additionally, the proposal should include a preliminary, high-level life cycle analysis (LCA) to demonstrate that the proposed technology will not create more CO_2 than is utilized and/or show that the CO_2 emissions are less than the process that it would replace. Projects will be selected based on the strength of proposed concepts and approach, prior progress made by the applicant in developing the technology, potential for

future and near-term commercialization, assessment of the technology's promise for substantive and cost-effective CO_2 mitigation, and reasonableness of proposed cost of the technology.

DOE is currently supporting multiple small- and large-scale R&D projects to demonstrate the technical and economic feasibility of CCS. While advances have been made to reduce the cost of implementation, cost remains a primary concern. Recent studies support the approach that CO_2 utilization should focus on identifying technologies and opportunities that assist in reducing CO_2 capture costs as a means to accelerate industrial-scale implementation of geologic storage. Consequently, technologies that support this approach are of particular interest.

Questions – Contact: Danielle Petrucci, danielle.petrucci@hq.doe.gov

d. Material Development for Ceramic-Metal Transitions that Facilitate Ceramic and Metal Joining and Flanging under High Temperature and Pressure Conditions

Economical and efficient heat transfer technologies applicable to high-temperature, high-pressure conditions are a common requirement for advanced fossil energy power generation systems. For example, power cycles based on steam on supercritical CO_2 are targeting temperatures in excess of 700 C to enable highly efficient performance. In these cycles, heat is transferred from a heat source such as an air- or oxy-fired coal boiler or natural gas turbine into a power cycle working fluid by means of heat exchange components such as boiler tubes, heat recovery steam generator, heat exchanger, or recuperator. Some of these heat exchange environments contain very large pressure differentials (20-25 MPa) while others may contain periodic or occasional pressure fluctuations. Alloys with the requisite corrosion resistance and mechanical properties tend to be expensive. Alternatively, many ceramic materials are stable to much higher temperatures providing an opportunity to improve cycle performance and improve durability. Ceramic components perform poorly in tension requiring specialized engineering, in particular with respect to joining with adjacent components. In other words, joining ceramics to other high temperature metallic components is seen as an enabling technology for high-performance heat transfer components and by extension high-efficiency power cycles.

Grant applications are sought for research and development to join candidate high-temperature ceramic materials and heat exchange components with high-temperature metallic components. Joining technology should be robust to pressure upsets. Target applications should focus on extraction of heat from fossil-fired combustion heat sources into working fluids or internally between working fluids within a steam or supercritical CO_2 power cycle.

Questions – Contact: Steve Richardson, steven.richardson@netl.doe.gov

e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Doug Archer, douglas.archer@hq.doe.gov

References: Subtopic a:

1. Mathur, K.B., Epstein, N., 1974, *Spouted Beds*, Academic Press, Inc, New York.

(ISBN: 978-0-12-480050-2) (http://www.sciencedirect.com/science/book/9780124800502)

2. Fernandez-Akarregi, A.R., Makibar, J., Lopez, G., 2013, Design and Operation of a Conical Spouted Bed Reactor Pilot Plant (25 kg/h) for Biomass Fast Pyrolysis, *Fuel Processing Technology*, Vol. 112, pp. 48-56 (http://www.researchgate.net/publication/236161756_Design_and_operation_of_a_conical_spouted_bed_reactor_pilot_plant_(25_kgh)_for_biomass_fast_pyrolysis)

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1. Leblanc, D.P. et al, 2011, *Application of Propane (LPG) Based Hydraulic Fracturing in the McCully Gas Field, New Brunswick, Canada*, Society of Petroleum Engineers, North American Unconventional Gas Conference and Exhibition, The Woodlands, Texas, SPE-144093-MS (https://www.onepetro.org/conference-paper/SPE-144093-MS)

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3. *2009,* Air Force Research Laboratory*, Propulsion and Power Rapid Response Research and Development (R&D) Support*, Advanced Propulsion Fuels Research and Development–Subtask: Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels. NETL. AFRL-RZ-WP-TR-2009-2206. (http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Life%20Cycle%20Analysis/EstGHGFtprntsAvFuels2009.pdf)

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5. Herzog, H., Drake, E., and Adams, E., 1997, *CO2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Change*, A White Paper Final Report. DE-AF22-96PC01257.

(https://sequestration.mit.edu/pdf/WhitePaper.pdf)

6. U.S. Department of Energy, *CO_2 Utilization Focus Area*, National Energy Technology Laboratory. (http://www.netl.doe.gov/research/coal/carbon-storage/research-and-development/co2-utilization).

References: Subtopic d:

1. Sommers, A., Wang, Q., Han, X., et al., 2010, Ceramics and Ceramic Matrix Composites for Heat Exchangers in Advanced Thermal Systems – A Review, *Applied Thermal Engineering,* Vol. 30, No. 11, pp. 1277-1291. (http://www.users.miamioh.edu/sommerad/ate_3016_final_paper_published.pdf)

2. Kee, R.J., Almand, B., Blasi, J., et al., 2011, The Design, Fabrication, and Evaluation of a Ceramic Counter-Flow Microchannel Heat Exchanger, *Applied Thermal Engineering*, Vol. 31, Issues 11-12, pp. 2004-2012. (http://www.sciencedirect.com/science/article/pii/S1359431111001414)

3. U.S. Department of Energy, National Energy Technology Laboratory, Advanced Combustion Systems Program. (http://www.netl.doe.gov/research/coal/energy-systems/advanced-combustion) - Combustion System Descriptions and Heat Exchanger Applications.

4. 2014, Supercritical CO2 Power Cycles Symposium, *Symposium 2014 – Resources*. (http://www.swri.org/4org/d18/sCO2/papers2014.htm)- Presentations and Manuscripts covering all aspects of Supercritical CO2 Power Cycles.

16. TECHNOLOGY TRANSFER OPPORTUNITIES: BASIC ENERGY SCIENCES

Maximum Phase I Award Amount: **$225,000**	*Maximum Phase II Award Amount:* **$1,500,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Applicants to TECHNOLOGY TRANSFER OPPORTUNITIES (TTO) should review the section describing these opportunities on page 7 of this document prior to submitting applications.

Grant applications are sought in the following subtopics:

a. Technology Transfer Opportunity: Synthesis of High Quality Graphene

Lawrence Berkeley National Laboratory has developed a technology for synthesizing high homogeneity, micrometer scale graphene sheets. One highly successful approach has been simultaneous vacuum thermal decomposition of two SiC substrates, placed in close, face-to-face proximity to each other. The thickness of the graphene is controlled by adjusting the annealing temperature and duration of heating. Atomic force microscopy measurements demonstrate the homogeneity of graphene is notably improved by this face-to-face method compared with other, conventional methods. This method does not require sophisticated fabrication, or elaborate specifications or additional materials for the restriction of the Si sublimation rate.

Graphene shows promising potential for a wide variety of technological applications such as post-CMOS digital electronics, single-molecule gas sensors, and spintronic devices, among others. For graphene to be

successfully applied to new devices, homogeneous growth of graphene with device-sized scale (micrometer) on a semiconducting or insulating substrate is essential.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Shanshan Li (shanshanli@lbl.gov; 510-486-5366)
TTO tracking number: ID-2831
Patent Status: U.S. patent 8,142,754, issued March 27, 2012.
USPTO Link: http://www.google.com/patents/US8142754

Questions – Contact: Bonnie Gersten, bonnie.gersten@science.doe.gov

b. Technology Transfer Opportunity: Minimal Disturbance Cell Injection System

The Lawrence Berkeley National Laboratory nanoinjector is a system where nanostructures such as carbon nanotubes, nanorods, etc. are bound to lectins and/or polysaccharides and prepared for administration to cells. The chemical attachment of the cargo eliminates need for a carrier solvent, which adds undesirable volume to the cell. Use of the injector is not limited to larger cells. In its current configuration the injector is attached to the tip of an atomic force microscope (AFM) probe. The cargo is released in the reducing environment within the cell's interior. The nanoneedle is then retracted by AFM control. The amount of cargo released within the cell can be adjusted by varying the amount of time the nanoneedle remains in the cell.

Molecular probes such as the quantum dot can be inserted into the cell and thus probe the cell's interior for fine details such as the presence of a specific molecule. The LBNL team has already been proven successful in delivering small numbers of protein-coated quantum dots into a line of mammalian cells. LBNL is seeking a company that would develop a cargo loading and release mechanism that would facilitate use of the nanoinjector as a "plug-and-play" technology for a variety of cargos.

Proposals in the areas of tissue engineering and biomedical research will be considered nonresponsive.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Shanshan Li (shanshanli@lbl.gov; 510-486-5366)
TTO tracking number: ID-2323
Patent Status: U.S. Patent 8,257,932, issued September 4, 2012.
USPTO Link: https://www.google.com/patents/US8257932

Questions – Contact: Mike Markowitz, mike.markowitz@science.doe.gov

PROGRAM AREA OVERVIEW: OFFICE OF BIOLOGICAL AND ENVIRONMENTAL RESEARCH

The Biological and Environmental Research (BER) Program supports fundamental, peer-reviewed research on complex systems in climate change, subsurface biogeochemistry, genomics, systems biology, radiation biology, radiochemistry, and instrumentation. BER funds research at public and private research institutions and at DOE laboratories. BER also supports leading edge National Scientific User Facilities including the DOE Joint Genome Institute (JGI), the Environmental Molecular Science Laboratory (EMSL), the Atmospheric Radiation Measurement (ARM) Climate Research Facility and instrumentation for structural biology research at the DOE Synchrotron Light and Neutron sources.

BER has interests in the following areas:

(1) **Biological Systems Science** integrates discovery- and hypothesis-driven science with technology development on plant and microbial systems relevant to DOE bioenergy mission needs. Systems biology is the multidisciplinary study of complex interactions specifying the function of entire biological systems—from single cells to multicellular organisms—rather than the study of individual components. The Biological Systems Science subprogram focuses on utilizing systems biology approaches to define the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms. Key questions that drive this research include: What information is encoded in the genome sequence? How is information exchanged between different sub-cellular constituents? What molecular interactions regulate the response of living systems and how can those interactions be understood dynamically and predictively? The approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into predictive computational models of biological systems that can be tested and validated.

The subprogram supports operation of a scientific user facility, the DOE Joint Genome Institute (JGI), and access to structural biology facilities at the DOE Synchrotron Light and Neutron Sources. Support is also provided for research at the interface of the biological and physical sciences and in radiochemistry and instrumentation to develop new methods for real-time, high-resolution imaging of dynamic biological processes.

(2) **The Climate and Environmental Sciences** subprogram focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges—both key to supporting the DOE mission. The subprogram supports an integrated portfolio of research from molecular-level to field-scale studies with emphasis on multidisciplinary experimentation and use of advanced computer models. The science and research capabilities enable DOE leadership in climate-relevant atmospheric-process research and modeling, including clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change modeling; integrated analysis of climate change impacts; and advancing fundamental understanding of coupled physical, chemical, and biological processes controlling contaminant mobility in the environment. The subprogram supports three primary research activities and two national scientific user facilities. Atmospheric System Research seeks to resolve the two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosols on the atmospheric radiation balance.

Environmental System Science supports research that provides scientific understanding of the effects of climate change on terrestrial ecosystems, the role of terrestrial ecosystems in global carbon cycling, and the role of subsurface biogeochemistry in controlling the fate and transport of energy-relevant elements.

Climate and Earth System Modeling focuses on development, evaluation, and use of large scale climate change models to determine the impacts of climate change and mitigation options.
Two scientific user facilities the Atmospheric Radiation Measurement (ARM) Climate Research Facility and the Environmental Molecular Sciences Laboratory (EMSL) provide the broad scientific community with technical capabilities, scientific expertise, and unique information to facilitate science in areas integral to the BER mission and of importance to DOE.

For additional information regarding the Office of Biological and Environmental Research priorities, click here.

17. ATMOSPHERIC MEASUREMENT TECHNOLOGY

Maximum Phase I Award Amount: **$225,000**	*Maximum Phase II Award Amount:* **$1,500,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

The Intergovernmental Panel on Climate Change (IPCC) recently released its Fifth Assessment Report (AR5), where it was reinforced that clouds and aerosols dominate uncertainties in climate feedbacks associated with future climate projections (Reference 1). The mission of the Atmospheric Radiation Measurement (ARM) Climate Research Facility is to provide the climate research community with strategically located in situ and remote sensing observations to improve the understanding and representation, in climate and earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface. The Atmospheric System Research (ASR) program brings together ARM expertise in continuous remote sensing measurements of cloud properties and aerosol influences on radiation with the expertise of in situ characterization of aerosol properties, evolution, and cloud interactions. The goal of ASR, in partnership with the ARM Facility, is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics to improve fundamental process-level understanding, with the ultimate goal to reduce the uncertainty in global and regional climate simulations and projections (Reference 2).

Measurements of aerosol and cloud particles under a range of atmospheric conditions are required to fully understand aerosol and cloud lifecycles, their interactions, and their impact on the radiation budget. Innovative measurement technologies are needed to provide this data, which is necessary both for process understanding and for evaluation of numerical models that are used to assess the climate change impacts to global and regional systems. Small aerial platforms, including unmanned aerial systems (UAS), tethered balloons, and kites, provide an innovative approach for making atmospheric measurements in conditions that are logistically difficult for ground-based measurements, that are too dangerous or cost-prohibitive for manned aircraft, or under operating conditions (e.g., slow airspeeds or low altitudes) that are more difficult for large or manned platforms. While small aerial platforms are gaining increased use in the scientific, civil, and defense arenas, there is still a lack of sophisticated observing capabilities for important aerosol, cloud, and associated meteorological state variables that have been miniaturized for deployment on such platforms.

Grant applications are sought for technology innovation in aerosol and cloud measurements to capitalize on the increasing utility of UAS platforms for scientific missions.

Grant applications submitted to this topic must propose Phase I bench tests of critical technologies. ("Critical technologies" refers to components, materials, equipment, or processes that overcome significant limitations to current capabilities.) In addition, grant applications should (1) describe the purpose and benefits of any

proposed teaming arrangements with government laboratories or universities, and (2) support claims of commercial potential for proposed technologies (e.g., endorsements from relevant industrial sectors, market analysis, or identification of potential spin-offs). Grant applications proposing only computer modeling without physical testing will be considered non-responsive.

Grant applications are sought in the following subtopics:

a. Aerosol and Cloud-Related Measurements from Small Aerial Platforms

Instrument packages developed to measure aerosol and cloud properties have been successfully deployed from research aircraft in a wide range of atmospheric conditions. However, traditional instrument packages typically are too large and heavy and/or require too much power to be used on small aerial platforms, such as UAS, tethered balloons, or kites. A need exists for instrument packages capable of installation on a small aerial platform with capabilities to measure properties of aerosols, cloud droplets, and/or glaciated hydrometeors. Grant applications are sought to develop lightweight and low power (suitable for sampling from UAS, tethersonde, or kite platforms) instruments for (1) cloud droplet/drizzle measurements (10–1000 μm size range), (2) accurate measurements of liquid water content and/or ice water content – techniques that distinguish phase of condensed water are high added value, (3) accurate measurements of water vapor concentration and local thermodynamic state that enable accurate calculation of relative humidity and/or supersaturation, (4) acquisition of high-resolution cloud particle images capable of distinguishing size and habit of ice particles as well as droplets in mixed-phase clouds, (5) a fast spectrometer for measurement of cloud condensation nuclei number concentrations over supersaturation ranges of the order 0.02% – 1%, (6) a spectrometer/counter for ice nuclei (IN) number concentrations over effective local temperatures down to -38 °C, and (7) a nephelometer to measure aerosol scattering (nominal wavelength 550 nm with a sensitivity of at least 1 M m-1; additional wavelengths may be proposed).

Instruments must be capable of operating on light-weight airborne platforms such as UAS's with little or no temperature or pressure controls. We are particularly interested in instruments that weigh less than 6 kg and require less than 150 W of power.

Questions – Contact: Rickey Petty, rick.petty@science.doe.gov (platform-related) or Ashley Williamson, ashley.williamson@science.doe.gov (sensor related)

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Ashley Williamson, ashley.williamson@science.doe.gov

References:

1. Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., et el, IPCC, 2013, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324. (http://www.climatechange2013.org/report/full-report/)

2. 2010, U.S. Department of Energy: Office of Science. Atmospheric System Research (ASR) Science and Program Plan. (http://science.energy.gov/~/media/ber/pdf/Atmospheric_system_research_science_plan.pdf).

3. Ivey, M., Verlinde, J., and Petty, R., et el., 2013. Polar Research with Unmanned Aircraft and Tethered Balloons, U.S. Department of Energy. DOE/SC-ARM-TR-135. (http://www.arm.gov/publications/tech_reports/doe-sc-arm-tr-135.pdf?id=6)

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18. TECHNOLOGIES FOR CHARACTERIZING AND MONITORING COMPLEX SUBSURFACE SYSTEMS

Maximum Phase I Award Amount: **$225,000**	*Maximum Phase II Award Amount:* **$1,500,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

Reactive transport models are increasingly used to model hydrobiogeochemical processes in complex subsurface systems (soils, rhizosphere, sediments, aquifers and the vadose zone) for many different applications and across a wide range of temporal and spatial (e.g., pore to core to plot to watershed) scales. With increasing computational capability it is possible to simulate the coupled interactions of complex subsurface systems with high fidelity. The predictive skill of these advanced models is limited, however, by the accuracy of the parameters that are used to populate the models and represent the system structure and intrinsic properties. Furthermore, robust testing of these increasingly complex models requires high fidelity measurements of the hydrobiogeochemical structure and functioning of the complex subsurface systems over the relevant spatial and temporal scales.

The focus of this topic is on the development of improved sensing systems for capturing the in-situ hydrobiogeochemical structure and functioning of complex subsurface systems because they serve as the substrate for natural, disturbed and managed terrestrial vegetation systems.

Grant applications submitted to this topic must describe why and how the proposed *in situ* fieldable technologies will substantially improve the state-of-the-art, include bench and/or field tests to demonstrate the technology, and clearly state the projected dates for likely operational deployment. New or advanced technologies, which can be demonstrated to operate under field conditions and can be deployed in 2-3 years, will receive selection priority. Claims of relevance to field sites or locations under investigation by DOE, or of commercial potential for proposed technologies, must be supported by endorsements from relevant site managers, market analyses, or the identification of commercial spin-offs. Grant applications that propose incremental improvements to existing technologies are not of interest and will be declined. Collaboration with government laboratories or universities, either during or after the SBIR/STTR project, may speed the development and field evaluation of the measurement or monitoring technology. BER funding to the National Laboratories is primarily through Scientific Focus Areas (SFAs). The Subsurface Biogeochemical Research (SBR)

supported SFAs, and the field sites where they conduct their research, are described at the following website: http://doesbr.org/research/sfa/index.shtml. The Terrestrial Ecosystem Science (TES) program also supports several interdisciplinary field research projects focused on carbon and nutrient cycling: http://tes.science.energy.gov/research/ameriflux.shtml; http://tes.science.energy.gov/research/criticalecosystems.shtml. These field research sites may also be appropriate venues for testing and evaluation of novel measurement and monitoring technologies. Proposed plans to conduct testing at these DOE supported research sites should be accompanied by a letter of support from the project PI.

Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements.

Grant applications are sought in the following subtopics:

a. Real-Time, In Situ Measurements of Hydrobiogeochemical and Microbial Processes in Complex Subsurface Systems

Sensitive, accurate, and real-time monitoring of hydrobiogeochemical processes are needed in subsurface environments, including soils, the rhizosphere, sediments, the vadose-zone and groundwaters. In particular, highly selective, sensitive, and rugged *in situ* devices are needed for low-cost field deployment in remote locations, in order to enhance our ability to monitor processes at finer levels of resolution and over broader areas. Therefore, grant applications are sought to develop improved approaches for the autonomous and continuous sensing of key elements such as carbon, nitrogen, sulfur and phosphorus *in situ*; improved methods to measure and monitor dissolved oxygen, vertically resolved soil moisture distributions, and groundwater age.

The ability to distinguish between the relevant oxidation states of redox sensitive elements such as iron, manganese, sulfur and other inorganics is of particular concern. Innovative approaches for monitoring multi-component biogeochemical signatures of subsurface systems is also of interest, as is the development of robust field instruments for multi-isotope and quasi-real time analyses of suites of isotope systems of relevance to hydrologic and biogeochemical studies (e.g. ^{2}H, ^{18}O, CH_4, CO_2, nitrogen compounds, etc.).

Grant applications must provide convincing documentation (experimental data, calculations, and simulation as appropriate) to show that the sensing method is both highly sensitive (i.e., low detection limit), precise, and highly selective to the target analyte, microbe or microbial association (i.e., free of anticipated physical/chemical/biological interferences). Approaches that leave significant doubt regarding sensor functionality in realistic multi-component samples and realistic field conditions will not be considered.

Grant applications also are sought to develop integrated sensing systems for autonomous or unattended applications of the above measurement needs. The integrated system should include all of the components necessary for a complete sensor package (such as micro-machined pumps, valves, micro-sensors, solar power cells, etc.) for field applications in the subsurface. Approaches of interest include: (1) automated sample collection and monitoring of subsurface biogeochemistry and microbiology community structure, (2) fiber optic, solid-state, chemical, or silicon micro-machined sensors; and (3) biosensors (devices employing biological molecules or systems in the sensing elements) that can be used in the field –

biosensor systems may incorporate, but are not limited to, whole cell biosensors (i.e., chemiluminescent or bioluminescent systems), enzyme or immunology-linked detection systems (e.g., enzyme-linked immunosensors incorporating colorimetric or fluorescent portable detectors), lipid characterization systems, or DNA/RNA probe technology with amplification and hybridization. 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.

Questions – Contact: David Lesmes, david.lesmes@science.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: David Lesmes, david.lesmes@science.doe.gov

References:

1. 2015, U.S. Department of Energy, Office of Biological & Environmental Research (BER), Climate and Environmental Science Division (CESD), *Subsurface Biogeochemical Research (SBR).* (http://science.energy.gov/ber/research/cesd/subsurface-biogeochemical-research/).

2. 2015, U.S. Department of Energy, Office of Biological & Environmental Research, Climate and Environmental Sciences Division (CESD), *Terrestrial Ecosystem Science (TES)*. (http://science.energy.gov/ber/research/cesd/terrestrial-ecosystem-science/).

3. 2012, U.S. Department of Energy, Office of Biological and Environmental Research, Climate and Environmental Sciences Division (CESD), *Strategic Plan*. DOE/SC-0151. (http://science.energy.gov/~/media/ber/pdf/CESD-StratPlan-2012.pdf).

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7. U.S. Department of Energy Office of Environmental Management (EM). (http://www.em.doe.gov).

8. U.S. Department of Energy Office of Legacy Management (LM). (http://energy.gov/lm/office-legacy-management).

19. CARBON CYCLE MEASUREMENTS OF ECOSYSTEMS AND THE BIOSPHERE

Maximum Phase I Award Amount: **$225,000**	*Maximum Phase II Award Amount:* **$1,500,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

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

The “First State of the Carbon Cycle Report (SOCCR)” (Reference 1) and the “Carbon Cycling and Biosequestration Report: (Reference 2) provides rough estimates of terrestrial carbon sinks for North America. Numerous working papers on carbon sequestration science and technology also describes research needs and technology requirements for sequestering carbon by terrestrial systems (Reference 3-5). Both documents call for advanced sensor technology and measurement approaches for detecting changes of atmospheric CO_2 properties and of carbon quantities of terrestrial systems (including biotic, microbial, and soil components). Such measurement technology would improve the quantification of CO_2, as well as carbon stock and flux, in the major sinks identified by the SOCCR report (see Figure ES.1 therein). Furthermore, the “U.S. Carbon Cycle Science Plan” (Reference 6) provides additional background on critical, overarching research needs related to carbon cycling in terrestrial ecosystems.

Grant applications submitted to this topic should (1) demonstrate performance characteristics of proposed measurement systems, and (2) show a capability for deployment at field scales ranging from experimental plot size (meters to hectares of land) to nominal dimensions of ecosystems (hectares to square kilometers). Phase I projects must perform feasibility and/or field tests of proposed measurement systems to assure a high degree of reliability and robustness. Combinations of stationary, remote and *in situ* approaches will be considered, and priority will be given to ideas/approaches for verifying biosphere carbon changes. Measurements using aircraft or balloon platforms must be explicitly linked to real-time ground-based measurements. Grant applications based on satellite remote sensing platforms are beyond the scope of this topic, and will be declined. Return to Top of Document 132.

Grant applications are sought in the following subtopic:

a. Miniaturized Spectroradiometers for Quantifying Terrestrial Ecosystems with Mobile and Unmanned Aerial Systems

Terrestrial models rely on detailed parameterizations representing ecosystem processes using trait data describing the vegetation in a given ecosystem. This trait data is often incomplete and derived from a single site, therefore providing an incomplete spatial and temporal representation of key vegetation and ecosystem characteristics (References 7-10). This vegetative and ecological data is often partitioned into

discrete plant functional types (PFTs) (current generation models use between five and sixteen PFTs to describe the entire planet) (Reference 11 and 12). As computational power increases it will be possible to provide models with more complex descriptions of ecosystems that replace the use of restrictive PFTs with temporally and spatially resolved trait-space descriptions of plants representing global terrestrial ecosystems. Development of the scientific understanding that will underlie robust trait maps derived from remote sensing observations will require the coupling of traditional trait measurements with the collection of near surface (i.e. leaf to landscape scales) spectral signatures. Currently the development and validation of such parameterization is limited by the ability to validate and scale process knowledge effectively from the leaf and plot scale to the landscape scale. Traditional aircraft and large payload Unmanned Aerial Systems (UASs) provide an excellent opportunity to tackle scaling issues but the cost, operational requirements, logistics, and scheduling limit the availability to a small number of research applications, and short temporal windows for data collection (Reference 13). The availability, sophistication, and ease of use of small to medium payload UASs has evolved rapidly in the last five years and at the same time the costs of the UAS platforms have decreased considerably. Affordable, light weight UASs offer the opportunity to conduct airborne measurements for upscaling key ecosystem properties useful for constraining and validating ESMs. However, the instrument packages required to measure the spectral characteristics of vegetation canopies - which are needed to develop physiological trait maps - far exceed the capability of these lightweight UASs. Thus, it would be a transformational step if spectroradiometers could be miniaturized to enable them to be flown on inexpensive, small, off-the-shelf UAS platforms. If available, this technology would rapidly accelerate ongoing efforts to scale key ecosystem traits to broader spatial scales and throughout critical vegetation development stages. Once validated at the plot and landscape scales, algorithms can be developed to allow temporal and spatial trait mapping across the globe – this would provide a transformational increase in trait data richness for ESMs, and when coupled with improved process knowledge, result in a marked reduction in model uncertainty.

Grant applications are sought for technology innovation to capitalize on the increasing utility of UAS platforms for scientific missions. There is an urgent need to accelerate the miniaturization of existing instrumentation and integration with UASs. High resolutions, lightweight, durable spectroradiometers, are needed to achieve this goal and should contain the following minimum technical specifications:

Wavelength Range: 350-2500nm
Spectral Resolution: <10nm across the full range
Spectral Bandwidths: <4nm across the full range
Minimal Spatial Footprint: 30cm diameter
Wavelength Reproducibility: 0.1nm
Minimum Integration Speed: 10ms VNIR, 1.0ms SWIR
Wavelength Accuracy: ±1nm VNIR, ±2nm SWIR
Noise equivalent Radiance (NER): <1.5x10-9 across the full range
Calibration Accuracy (NIST): ±5% @400nm, ±4% @700nm, ±7% @2200nm
Operation Time: Sufficient power for 30 minutes of operation
Instrument Dimension: Must be compatible with small to medium UAS platforms
Mass: Fully operational system must be <2.5kg
Software and Data Integration Capability: Capable of storing potential data streams from 30 minute missions. The data management software must be capable of spatial and temporal integration and georeferencing. The software must also be capable of producing a seamless assembly of data streams from multiple sensors e.g. Thermal IR camera - possibly on the same or additional UASs. Instrument

software should be capable of synchronizing with the UASs flight planning software to enable instrument actuated transition through the flight plan.

Questions – Contact: Daniel Stover, daniel.stover@science.doe.gov

b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Daniel Stover, daniel.stover@science.doe.gov

References:

1. King, A.W et al., 2007, The N. American Carbon Budget and Implications for the Global Carbon Cycle: EDS, *The First State of the Carbon Cycle Report (SOCCR), U.S.* Climate Change Science Program Synthesis and Assessment Product, Version 2.2, pp. 239. (http://cdiac.ornl.gov/SOCCR/pdf/SAP2.2_Entire_Report_March2007.pdf)

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20. TECHNOLOGY TRANSFER OPPORTUNITIES: BIOLOGICAL AND ENVIRONMENTAL RESEARCH

Maximum Phase I Award Amount: **$225,000**	*Maximum Phase II Award Amount:* **$1,500,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

Applicants to TECHNOLOGY TRANSFER OPPORTUNITIES (TTO) should review the section describing these opportunities on page 7 of this document prior to submitting applications.

DOE's Office of Biological and Environmental Research (BER) Genomic Science Program supports DOE mission-driven fundamental research to identify the foundational principles that drive biological systems. Development of innovative approaches for sustainable bioenergy production will be accelerated by a systems biology understanding of non-food plants that can serve as dedicated cellulosic biomass feedstocks and microbes capable of deconstructing biomass into their sugar subunits and synthesizing next generation biofuels from cellulosic biomass. Genomic Science Program research also brings the -omics driven tools of modern systems biology to bear for analyzing interactions among organisms that form biological communities and between organisms and their surrounding environments.

BER established three Bioenergy Research Centers (BRCs) in 2007 to pursue the basic research underlying a range of high-risk, high-return biological solutions for bioenergy applications. Advances resulting from the BRCs are providing the knowledge needed to develop new biobased products, methods, and tools that the emerging biofuel industry can use. The three Centers are based in the Southeast, the Midwest, and the West Coast, with partners across the nation. DOE's Lawrence Berkeley National Laboratory leads the DOE Joint BioEnergy Institute (JBEI) in California, DOE's Oak Ridge National Laboratory leads the BioEnergy Science Center (BESC) in Tennessee, and the University of Wisconsin-Madison leads the Great Lakes Bioenergy Research Center (GLBRC).

The goal for the three BRCs is to understand the biological mechanisms underlying biofuel production from cellulosic biomass so that these mechanisms can be improved, and used to develop novel, efficient bioenergy strategies that can be replicated on a mass scale. Detailed understanding of many of these mechanisms form the basis for the BRCs' inventions and tech-transfer opportunities, which enable the development of technologies that are critical to the growth of a biofuels industry.

Successful applicants will propose R&D that will lead to biofuel commercialization utilizing one of the TTOs listed below. Applications that propose technologies related to a TTO but that do not directly utilize a TTO will not be funded. Applications should include sufficient preliminary data and scientific detail so that expert reviewers will understand both the potential benefits and the challenges that may be encountered in carrying out the proposed research. Challenges should be identified, and solutions should be proposed that will explain how the PI's team will overcome the challenges. Applications should address potential risks such as biocontainment challenges as well as strategies to mitigate those risks.

Questions – Contact: Prem Srivastava, prem.srivastava@science.doe.gov

Grant applications are sought in the following subtopics:

a. Technology Transfer Opportunity: Engineering Polyketide Synthases for Production of Fuels

Joint BioEnergy Institute (JBEI) researchers are using synthetic biology to engineer polyketide synthases (PKSs) that can be used to produce carboxylic acids and lactones for biofuel production. Carboxylic acids can easily be converted to an ester biofuel. The JBEI team is the first to design PKSs to synthesize biofuels or their immediate precursors. Some of the longer-chain esters that can be produced by the JBEI PKSs could be used in biodiesel blends. Shorter chain esters and the lactones could be used as petroleum additives or in non-hydrophilic, advanced biofuel blends compatible with current fuel infrastructure. Because the JBEI process allows controlled engineering, ester linkages can be placed so that combustion properties of the resulting biofuel are enhanced.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJIB-2540
Patent Status: Issued US Patent
USPTO Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=1&p=1&f=G&l=50&d=PTXT&S1=8,420,833.PN.&OS=PN/8,420,833&RS=PN/8,420,833
Website: http://ipo.lbl.gov/lbnl2540/

b. Technology Transfer Opportunity: Irreversible, Low Load Genetic Switches

Recombinases that have been conclusively demonstrated to work orthogonally are non-cross-reacting and do not cause unpredictable recombination events. Researchers at the Joint BioEnergy Institute (JBEI) have developed novel nucleic acid constructs containing matched orthogonal site selective recombinases. The JBEI invention removes the ability of a cell to access certain genes and enables the concurrent use of multiple recombinases. This system enables multiple genes to be turned on or off at different states of an organism's lifecycle, which has both research and industrial applications. It offers improved reliability over other approaches by ensuring that circuits proceed to completion rather than equilibrating. Potentially, these devices could be used to construct an expression system with low load on the cell, a very low level of basal expression and an extremely high level of expression after induction. This could be useful where a growth phase and a production/manipulation phase need to be kept distinct. Using this sort of toggle, many changes can be made at once to cell physiology.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJIB-2593
Patent Status: US Patent Application
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=2&p=1&f=G&l=50&d=PG01&S1=088,288.APN.&OS=APN/088,288&RS=APN/088,288
Website: http://ipo.lbl.gov/lbnl2593/

c. Technology Transfer Opportunity: Directed Evolution of Microbe Producing Biofuels Using In Vivo Transcription Factor Based Biosensors

JBEI researchers developed a method of using transcription factors expressed in vivo to evolve, screen, and select for microorganisms producing an intracellular small molecule of interest, such as a short chain alcohol. Biosensors composed of transcription factors and their cognate promoters are designed and constructed to be capable of binding the particular molecule of interest. For the biofuels industry, an in vivo biosensor in a microorganism, such as E. coli, for the detection of short-chain alcohols can be used to develop high-throughput selections and screens to engineer microorganisms producing alcohol-based biofuel molecules. This approach provides an alternative to low throughput methods, such as chromatography, for metabolite detection. The JBEI invention improves screening throughput and exhibits greater sensitivity as compared to high-throughput colorimetric screens. Downstream application of the invention as a selection method could allow for direct, dynamic evolution of strains without the need for screening.
The JBEI technology focuses on bacterial transcription factors and their cognate promoters. This class of transcription factors has been shown to bind to a broad range of industrial and commercial molecules.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJIB-2710
Patent Status: US Issued Patent

USPTO Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=8,552,169.PN.&OS=PN/8,552,169&RS=PN/8,552,169
Website: http://ipo.lbl.gov/lbnl2710/

d. Technology Transfer Opportunity: Biosynthetically Produced Pinene for Jet Fuel or Chemical Applications

A Joint BioEnergy Institute (JBEI) research team has constructed a metabolic pathway to produce the monoterpene pinene, an immediate chemical precursor to a potential jet fuel. Pinene is typically derived from turpentine, a byproduct of pine resin distillation. The JBEI technology could open the door to more economical and sustainable production of a vital transportation fuel. The researchers modified host cells, rerouting the isoprenoid pathway to produce geranyl pyrophosphate and then pinene, using selected synthases. Researchers confirmed that their technology is capable of producing pinene from either xylan or cellobiose.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJIB-2895
Patent Status: US Patent Application
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=1&p=1&f=G&l=50&d=PG01&S1=091,818.APN.&OS=APN/091,818&RS=APN/091,818
Website: http://ipo.lbl.gov/lbnl2845/

e. Technology Transfer Opportunity: Enhancing Fatty Acid Production by Regulation of fadR Expression

Researchers at the DOE Joint BioEnergy Institute (JBEI) have developed a genetically modified host cell that increases production of fatty acids and their derivatives. Specifically, the JBEI team found that increased concentration of cellular fadR, a transcriptional factor protein that regulates genes responsible for fatty acid activation and several genes in the fatty acid degradation pathway, lowers fatty acid degradation rate and enhances unsaturated fatty acid biosynthesis, resulting in an increase in total fatty acid production.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJIB-2917
Patent Status: US and Canadian Patent Applications
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=2&p=1&f=G&l=50&d=PG01&S1=549,034.APN.&OS=APN/549,034&RS=APN/549,034
Website: http://ipo.lbl.gov/lbnl2917/

f. Technology Transfer Opportunity: Transcription Factor-based Biosensors for Detection of Dicarboxylic Acids

This invention comprises a biosensor-based system for accurate detection of exogenous dicarboxylic acids in liquid or solid media and in vivo detection of endogenously produced diacids within a single host. Microorganisms are highly adept at sensing and responding to small-molecules in their environment. For example, transcription factors binding dicarboxylic acids can modulate expression of one or more reporter genes downstream of the transcription factor's cognate promoter. By monitoring the expression of the reporter genes dicarboxylic acid concentration can be readily measured. Exemplary reporter genes may encode for beta-galactosidase, a fluorescent protein, an antibiotic resistance protein, or a biosynthetic pathway. This strategy has been implemented for detection of short-chain alcohols using an E. coli strain heterologously expressing a short-chain alcohol responsive transcription factor. In addition to transcription factors, a dicarboxylic acid specific catabolic operon can couple exogenous dicarboxylic acid concentration to the specific growth rate of a biosensor microorganism.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EJBI-2982
Patent Status: Issued US Patent
USPTO Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=8652804.PN.&OS=PN/8652804&RS=PN/8652804
Website: http://ipo.lbl.gov/lbnl2820_2825_2878_2892_3014/

g. Technology Transfer Opportunity: Bacterial Overproduction of Methyl Ketones from Sugar

Researchers at the Joint BioEnergy Institute (JBEI) have developed a bacterial strain that can overproduce medium-chain (such as C11 to C15) methyl ketones from glucose. The methyl ketones could be blended with diesel fuel to yield a viable transportation fuel derived, in part, from renewable resources. Methyl ketones, such as 2-undecanone and 2-tridecanone, are also used in the flavor and aroma industries.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EIB-3063
Patent Status: US and EPO Patent Applications
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=1&p=1&f=G&l=50&d=PG01&S1=354,510.APN.&OS=APN/354,510&RS=APN/354,510
Website: http://ipo.lbl.gov/lbnl3063/

h. Technology Transfer Opportunity: Long alkyl Chain Alcohols as Co-solvent, Precipitant and Extraction Medium in Ionic Liquid Pretreatment

JBEI researchers developed a method to use long chain alcohols such as octanol or hexanol as anti-solvents to precipitate dissolved cellulose in ionic liquids. This method is advantageous compared with the most

commonly used water anti-solvents. Water is miscible with ionic liquids, hampering, recycling and reuse of both ionic liquids and anti-solvents. Longer chain alcohols are immiscible with ionic liquids, enabling easier separation of both ionic liquids and octanol. The invented method provides multiple potential technical advantages: Recycle of ionic liquids and possible extraction of depolymerized lignin fractions in octanol. The resulting solids after solid/liquid separation are highly digestible by cellulolytic enzymes and no wash is needed before loading of enzymes. Recycled IL can directly reused for pretreatment without further purification and concentration.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: 2013-105
Patent Status: US Patent Application
USPTO Link: Not yet published

i. Technology Transfer Opportunity: Production of Fatty-Acid-Derived Biofuels and Chemicals in Saccharomyces Cerevisiae

Joint BioEnergy Institute (JBEI) researchers have developed a method of genetically engineering budding yeast Saccharomyces cerevisiae (S. cerevisiae) to produce free fatty acids, fatty alcohols and biodiesels directly from simple sugars. As indicated in their Metabolic Engineering publication, the researchers demonstrated that S. cerevisiae provides a platform for a scalable route to key chemicals.

Rather than swap out individual fatty acid biosynthesis genes to enhance production, the Berkeley Lab team replaced the native promoters of all fatty acid biosynthesis genes with a strong constitutive promoter, yielding a strain that overproduces fatty acid. To augment triacylglycerol (TAG) accumulation, the researchers also overexpressed key fatty acid and TAG biosynthesis enzymes. Depending on the choice of converting enzyme, this engineered strain could produce and secrete directly into the culture medium fatty acid ethyl esters (biodiesel), free fatty acids, or fatty alcohols.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: 2013-113
Patent Status: US and Foreign Patent Applications
USPTO Link: http://www.freepatentsonline.com/WO2015013674A2.html
Website: http://ipo.lbl.gov/lbnl2013-113/

j. Technology Transfer Opportunity: Gene Modification to Increase Drought and Flood Tolerance in Plants

Researchers at the Joint BioEnergy Institute (JBEI) have used recombinant nucleic acid techniques to overexpress a gene — SAB18 — to increase plants' tolerance to both drought and flooding. SAB18, found in rice and other grass plants, is involved in carbohydrate and nucleotide metabolism and is responsible for a plant's natural tolerance to variations in water availability. Plants that are modified to over-express this gene have been shown to remain greener, taller, and more erect when subjected to extreme water conditions. When compared to natural plants under similar conditions, the viability and health of SAB18 modified rice plants increased substantially.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: 2014-108
Patent Status: US Patent Application
USPTO Link: Not yet published
Website: http://ipo.lbl.gov/lbnl2014-108/

k. Technology Transfer Opportunity: Production of 1-Deoxyxylulose-5-Phosphate (DXP)

Host Cells and Methods for Producing 1-deoxyxylulose-5-phosphate. Novel routes into the microbial DXP-based isoprenoid pathway have been discovered that increase the theoretical yield of isoprenoid-based fuels and chemicals from sugars. These routes allow more direct conversion of carbon to terpenoid compounds circumventing the typical, but inherently inefficient, route to DXP. Terpenoids are key ingredients in flavors and fragrances and offer a pathway to naturally derived isoprenoid-based biofuels and materials.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: EIO-3006
Patent Status: US Patent Application
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=1&f=G&l=50&d=PG01&p=1&S1=587,826.APN.&OS=APN/587,826&RS=APN/587,826
Website: http://ipo.lbl.gov/lbnl3006/

l. Technology Transfer Opportunity: Transgenic Cyanobacteria: A Novel Direct Secretion of Glucose for the Production of Biofuels

A direct secretion of glucose by transgenic cyanobacteria creates an extremely efficient, cost effective feedstock for the production of ethanol. The cells can be recycled for repeated glucose harvest.

Licensing Information:
University of Texas at Austin
Contact: Hugh Li (hli@otc.utexas.edu; 512-471-9055)
TTO Tracking Number: UT Tech ID: 5288 BRO
Patent Status: 1 issued patent: 7803601, issued 9/28/2010; 1 application: 12/877,785 filed on 9/8/2010
USPTO Link:
http://portal.uspto.gov/pair/view/BrowsePdfServlet?objectId=GDUY5UOTPPOPPY5&lang=DINO;
http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=/netahtml/PTO/srchnum.html&r=1&f=G&l=50&s1=20110003345.PGNR.&OS=DN/20110003345&RS=DN/20110003345
Website: Related technology: http://www.otc.utexas.edu/ATdisplay.jsp?id=210
Additional Information about TTO: Can be used to convert CO2 to useful energy course through a renewable and recyclable process

m. Technology Transfer Opportunity: Ethanol Tolerant Yeast for Improved Production of Ethanol from Biomass

UW–Madison researchers have developed a method to impart ethanol tolerance to yeast. The toxicity of alcohol to microbes such as yeast is a bottleneck in the production of ethanol from biomass-derived sugars through fermentation. The Elongase 1 gene encodes ELO1, an enzyme involved in the biosynthesis of unsaturated fatty acids in yeast. This gene could be incorporated into an industrial yeast strain to increase the amount of ethanol produced from biomass. An industrial fermentation yeast strain with increased ethanol tolerance could be widely applicable in reducing costs and energy consumption.

Licensing Information:
University of Wisconsin – Madison
Contact: Mark Staudt (mstaudt@warf.org; 608-265-3084)
TTO Tracking Number: P100228US02
Patent Status: 8,178,331; 13/232327; 61/383185
USPTO Link: http://www.warf.org/documents/ipstatus/P100228US02.PDF
Website: http://www.warf.org/home/technologies/clean-technology/biofuels-renewable-fuels/summary/ethanol-tolerant-yeast-for-improved-production-of-ethanol-from-biomass-p100228us02.cmsx

n. Technology Transfer Opportunity: Genes for Xylose Fermentation, Enhanced Biofuel Production in Yeast

UW–Madison researchers have identified 10 genes in yeast that are involved in xylose fermentation. Efficient fermentation of biofuels and biorenewable chemicals from biomass-derived sugars would benefit from microbes that can utilize both glucose and xylose. These genes could be used to create an organism by modifying one that normally utilizes glucose to one that can ferment both xylose and glucose for enhanced biofuel production. These genes may be used in various combinations to produce useful industrial strains.

Licensing Information:
University of Wisconsin – Madison
Contact: Mark Staudt (mstaudt@warf.org; 608-265-3084)
TTO Tracking Number: P100245US03
Patent Status: 8,795,996; 13/441381; 61/516650; 61/509849; 14/307128
USPTO Link: http://www.warf.org/documents/pubapps/P100245US03%20Published%20Application.PDF
Website: http://www.warf.org/home/technologies/clean-technology/biofuels-renewable-fuels/summary/genes-for-xylose-fermentation-enhanced-biofuel-production-in-yeast-p100245us03.cmsx

o. Technology Transfer Opportunity: Production of Polyhydroxyalkanoates with a Defined Composition from an Unrelated Carbon Source

UW–Madison researchers have developed recombinant E. coli capable of producing high yields of medium chain length polyhydroxyalkanoates from non-lipid, carbohydrate sources. The researchers previously designed and built a bacterial strain that produces high levels of C12 fatty acids (see WARF reference number P09329US02). This strain has been further modified by deleting various fad genes implicated in

the breakdown of fatty acids. Also, the bacteria cells incorporate several genes taken from other species to increase conversion efficiency.

Licensing Information:
University of Wisconsin – Madison
Contact: Jennifer Gottwald (jennifer@warf.org; 608-262-5941)
TTO Tracking Number: P120377US02
Patent Status: 13/833230; 61/699044
USPTO Link: http://www.warf.org/documents/pubapps/P120377US02%20Published%20Application.pdf
Website: http://www.warf.org/technologies/summary/P120377US02.cmsx

p. Technology Transfer Opportunity: Organic Acid-Tolerant Microorganisms and Uses Thereof for Producing Organic Acids

UW–Madison researchers have genetically modified microorganisms to better tolerate organic acids like 3HP, acrylic acid and propionic acid. In the modified bacteria, the acsA gene is replaced or deleted. This leads to increased organic acid tolerance. The modified microorganisms are cyanobacteria such as HP or acrylic acid.

Licensing Information:
University of Wisconsin – Madison
Contact: Jennifer Gottwald (jennifer@warf.org; 608-262-5941)
TTO Tracking Number: P120017US02
Patent Status: 8,715,973; 13/798835; 61/647001; 8,846,354; 14/200747; 8,846,329; 14/200686
USPTO Link: http://www.warf.org/documents/ipstatus/P120017US02.PDF
Website: http://www.warf.org/technologies/summary/P120017US02.cmsx

q. Technology Transfer Opportunity: Fatty Acid-Producing Hosts

UW–Madison researchers have developed genetically modified E. coli that are capable of overproducing fatty acid precursors for medium- to long-chain hydrocarbons. The modified bacteria were transformed with exogenous nucleic acids to increase the production of acyl-ACP or acyl-CoA, reduce the catabolism of fatty acid products and intermediates, and/or reduce feedback inhibition at specific points in the biosynthetic pathway. The modified bacteria can be cultured in the presence of sugars to produce fatty acids. The fatty acid products formed during fermentation then can be separated from the fermentation media via a two-phase separation process or other method. The separated products can be used directly or as feedstock for subsequent reactions, including conversion to medium- and long-chain hydrocarbons. Production of medium-chain and long-chain hydrocarbons for use as biofuels or specialty chemicals.

Licensing Information:
University of Wisconsin – Madison
Contact: Jennifer Gottwald (jennifer@warf.org; 608-262-5941)
TTO Tracking Number: P09329US02
Patent Status: 8,617,856; 12/984343; 61/292918
USPTO Link: http://www.warf.org/documents/ipstatus/P09329US02.PDF
Website: http://www.warf.org/technologies/summary/P09329US02.cmsx

r. Technology Transfer Opportunity: High Calorie and Nutritional Content Plants or Plant Seeds

MSU researchers have developed a suite of technologies that may be used for several purposes, depending on implementation. The technolgies include i) the wrinkle 1 regulatory gene, which switches on expression of enzymes involved in lipid production; ii) pyruvate kinase genes downstream of wrinkle 1, which may be used to increase lipids or certain amino acids, and iii) diacylglycerol acyl transferase (DAGAT) genes, which may be used to increase lipid production. This suite of technologies may be used to increase oil content in plant seeds or alternatively plant leafy tissues. High oil leafy tissues may be used as enhanced forage crops or for vegetable and biodiesel production Leaf oil contents of greater than 10% have been demonstrated. Forage crops may also be enhanced by increased production of amino acids.

Licensing Information:
Michigan State University
Contact: Tom Herlache, (herlache@msu.edu; 517-884-1656)
TTO Tracking Number: TEC2000-0092; TEC2005-0025; TEC2009-0022; TEC2013-0040; TEC2015-0075
Patent Status: wrinkled 1: US 7,230,160 and foreign equivalents. Target genes of wrinkled 1: U.S. 8,426,676; U.S. 8,362,319. Production of oil in vegatative tissues: U.S. 14/046,504. Increased calorific content of plant biomass, provisional application filed.
USPTO Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=2&f=G&l=50&co1=AND&d=PTXT&s1=7,230,160&OS=7,230,160&RS=7,230,160
Websites: http://msut.technologypublisher.com/technology/6996; http://msut.technologypublisher.com/technology/7894; http://msut.technologypublisher.com/technology/13009

s. Technology Transfer Opportunity: A Method to Produce 3-Acetyl-1, 2-Diacyl-sn-glycerols (ac-TAGs)

Michigan State University's inventions provide a source and production method for novel plant oils, acetyl-triacylglycerols (ac-TAGs), with possible uses as biodiesel-like biofuel and/or as low-fat food ingredients. By combining an ac-TAG-related enzyme with a method for catalyzing large-scale synthesis of ac-TAGs, in a single crop, many benefits can be obtained. The inventions have lower viscosity and fewer calories per mole than TAGs. Pilot experiments by the inventors have achieved approximately a 60 mole percent accumulation of ac-TAGs in seed oil.

Licensing Information:
Michigan State University
Contact: Tom Herlache, (herlache@msu.edu; 517-884-1656)
TTO Tracking Number: TEC2009-0108
Patent Status: U.S. 13/519,660 Pending
USPTO Link: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PG01&s1=%2213%2F519,660%22&OS=%2213/519,660%22&RS=%2213/519,660%22
Website: http://msut.technologypublisher.com/technology/5989

t. Technology Transfer Opportunity: A Novel Integrated Biological Process for Cellulosicethanol Production Featuring High Ethanol Productivity, Enzyme Recycling, and Yeast Cells Reuse

MSU's technology provides a method of recycling unhydrolized recalcitrant solids in a biomass processing facility. The recycling process addresses current biomass processing issues that lead to high enzyme loading, slow xylose fermentation, and low ethanol productivity. Recycling of unhydrolyzed solids after a short enzymatic digestion enables use of 33% less enzyme, and increases ethanol productivity 2-3X in comparison to standard processes.

Licensing Information:
Michigan State University
Contact: Tom Herlache, (herlache@msu.edu; 517-884-1656)
TTO Tracking Number: TEC2012-0035
Patent Status: U.S. 14/251,921 Pending
USPTO Link http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=/netahtml/PTO/srchnum.html&r=1&f=G&l=50&s1=20140227757.PGNR.&OS=DN/20140227757&RS=DN/20140227757

u. Technology Transfer Opportunity: Advanced Biomass Tree Crops

Cellulose is a complex carbohydrate that serves as the basic structural component of plant cell walls. It accounts for roughly one-third of all vegetal matter, making it the most common organic compound on earth. Due to its ubiquitous nature, cellulose and its derivatives are key resources for the agriculture, forestry, textile, and paper industries. For these industries that rely on plant biomass, profitability is directly related to the quantity and quality of cellulose harvested from crops. However, until now, there have been no known methods of genetically controlling the quantity or quality of cellulose synthesized in plant species through direct regulation. MSU's suite of technologies provide genes for increasing cellulose and/or hemicellulose production in trees, and promoter "switches" that turn on expression of the trait genes in woody tissues.

Licensing Information:
Michigan State University
Contact: Tom Herlache, (herlache@msu.edu; 517-884-1656)
TTO Tracking Number: TEC2009-0131, TEC2011-0100, TEC2013-0123, TEC2014-0049
Patent Status: U.S. 13/821,095 Pending; U.S. 14/381,040 Pending; U.S. 14/540,320 Pending
USPTO Link http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=/netahtml/PTO/srchnum.html&r=1&f=G&l=50&s1=20150052641.PGNR.&OS=DN/20150052641&RS=DN/20150052641
Website: http://msut.technologypublisher.com/technology/8100

v. Technology Transfer Opportunity: Switchable Ionic Liquids for Biomass Pretreatment and Enzymatic Hydrolysis

This invention addresses the challenge that current ionic liquids are excellent at pretreating biomass, but are generally incompatible with enzymatic hydrolysis. JBEI researchers identified properties of ionic liquids that have the greatest impact on enzyme performance and how to manipulate these. The ionic liquid can be switched to a form compatible with enzymatic hydrolysis of cellulose following pretreatment, and then

switched back to efficiently pretreat biomass. By switching from one form to another, this novel ionic liquid can be used to efficiently pretreat biomass, and then—without having to remove the ionic liquid—be used in its enzyme compatible form for saccharification of the resulting cellulose.

Licensing Information:
Lawrence Berkeley National Laboratory
Contact: Peter Matlock (pymatlock@lbl.gov; 510-486-5803)
TTO Tracking Number: 2014-064
Patent Status: US Patent Application
USPTO Link: Not yet published

w. Technology Transfer Opportunity: Cell-Free System for Combinatorial Discovery of Enzymes Capable of Transforming Biomass for Biofuels

UW-Madison researchers have developed compositions and methods that expand the ability to make, express and identify target polypeptides, including enzymes capable of enhancing the deconstruction of biomass into fermentable sugars. This approach uses a cell-free system to express enzymes and other polypeptides in a combinatorial manner. Because the system is cell-free, the enzymes can be assayed without intermediate cloning steps or purification of the protein products. This system also is more reliable than conventional methods for analyzing biomass transformation because it does not utilize living systems, which could rapidly consume soluble sugars. This system could be used to efficiently screen enzyme combinations for effective deconstruction of biomass from different feedstocks and under different conditions.

Licensing Information:
University of Wisconsin – Madison
Contact: Jennifer Gottwald (jennifer@warf.org; 608-262-5941)
TTO Tracking Number: P08301US02
Patent Status: 8,945,902; 12/792156; 61/183243
USPTO Link: http://www.warf.org/documents/ipstatus/P08301US02.pdf
Website: http://www.warf.org/home/technologies/clean-technology/biofuels-renewable-fuels/summary/cell-free-system-for-combinatorial-discovery-of-enzymes-capable-of-transforming-biomass-for-biofuels-p08301us02.cmsx

x. Technology Transfer Opportunity: Multifunctional Cellulase and Hemicellulase

UW–Madison researchers have engineered a multifunctional polypeptide capable of hydrolyzing cellulose, xylan and mannan. It is made of the catalytic core of Clostridium thermocellum Cthe_0797 (also called CelE), a linker region and a cellulose-specific carbohydrate binding module (CBM3). C. thermocellum is a well-known cellulose-degrading bacterium whose genome has been sequenced, annotated and published. Multifuncional enzymes could simplify the enzyme cocktail needed for biomass conversion, thereby reducing costs.

Licensing Information:
University of Wisconsin – Madison
Contact: Jennifer Gottwald (jennifer@warf.org; 608-262-5941)
TTO Tracking Number: P120371US02

Patent Status: 14/030290; 61/703063
USPTO Link: https://intranet.warf.org/departments/patenting/Files/P120371/P120371US02%20-%20Patent%20Application%20-%202013-09-18.PDF
Website: http://www.warf.org/technologies/summary/P120371US02.cmsx

PROGRAM AREA OVERVIEW: OFFICE OF NUCLEAR PHYSICS

Nuclear physics (NP) research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which in turn determines the essential physical characteristics of the universe. The primary mission of the Nuclear Physics (NP) program is to develop and support the scientists, techniques, and facilities that are needed for basic nuclear physics research and isotope development and production. 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 laboratories and accelerator facilities, and at universities. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) allows detailed studies of how quarks and gluons bind together to make protons and neutrons. In an upgrade currently underway, the CEBAF electron beam energy will be doubled from 6 to 12 GeV. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) is forming new states of matter, which have not existed since the first moments after the birth of the Universe; a beam luminosity upgrade is currently underway. NP is supporting the development of a future Facility for Rare Isotope Beams (FRIB) currently under construction at Michigan State University. The NP community is also exploring opportunities with a proposed electron-ion collider.

The NP program also supports research and facility operations directed toward 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) which provides stable and radioactive beams as well as a variety of species and energies; a local program of basic and applied research at the 88-Inch Cyclotron of the Lawrence Berkeley National Laboratory (LBNL); the operations of accelerators for in-house research programs at two universities (Texas A&M University and the Triangle Universities Nuclear Laboratory (TUNL) at Duke University), which provide unique instrumentation with a special emphasis on the training of students; non-accelerator experiments, such as large standalone detectors and observatories for rare events. Of interest is R&D related to future experiments in fundamental symmetries such as neutrinoless double-beta decay experiments and measurement of the electric dipole moment of the neutron, where extremely low background and low count rate particle detections are essential. Another area of R&D is rare isotope beam capabilities, which could lead to a set of accelerator technologies and instrumentation developments targeted to explore the limits of nuclear existence. By producing and studying highly unstable nuclei that are now formed only in stars, scientists could better understand stellar evolution and the origin of the elements.

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

For additional information regarding the Office of Nuclear Physics priorities, click here.

21. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Large scale data storage and processing systems are needed to store, access, retrieve, distribute, and process data from experiments conducted at large facilities, such as Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC) and the Thomas Jefferson National Accelerator Facility (TJNAF). In addition, data acquisition for the Facility for Rare Isotope Beams (FRIB) will require unprecedented speed and flexibility in collecting data from the new flash ADC based detectors. Experiments at such facilities are extremely complex, involving thousands of detector elements that produce raw experimental data at rates in excess of a GB/sec, resulting in the annual production of data sets of hundred Terabyte (100 TB) to Petabyte (PB) scale. Data sets of many 10s to 100s of TB are currently distributed to institutions worldwide for analysis, and with the increasing data generation rates seen at RHIC, PB scale datasets are anticipated. Research on the management of such large data sets, and on high speed, distributed data acquisition will be required to support these large scale nuclear physics experiments.

All grant applications should explicitly show relevance to the DOE nuclear physics program. In addition, applications should be informed by prior practice in nuclear physics applications, commercially available products, and emerging technologies. We note that a proposal that advocates incremental improvements or moderate levels of innovation may nonetheless have an enormous impact in the right context. Such proposals must of course make their case convincingly, as they may otherwise be considered non-responsive.

Grant applications are sought only in the following subtopics:

a. Large Scale Data Processing and Distribution

A trend in nuclear physics is to maximize the availability of distributed storage and computing resources by constructing end-to-end data handling and distribution systems, using web services or data grid infrastructure software (such as Globus, Condor or xrootd), with the aim of achieving fast data processing and/or increased data availability across many compute facilities.

Grant applications are sought for (1) hardware and/or software techniques to improve the effectiveness and reduce the costs of storing, retrieving, and moving such large volumes of data, including but not limited to automated data replication coupled with application-level knowledge of data usage, data transfers to Tier 2 and Tier 3 centers from multiple data provenance, to achieve the lowest wait-time or fastest data processing and maximal coordination (2) effective new approaches to data mining or data analysis through data discovery or restructuring (examples of such approaches might include fast information retrieval through advanced MetaData searches or in-site data reduction, and repacking for remote analysis and data access); (3) new tools for co-scheduling compute and storage resources for data-intensive high performance computing tasks, such as user analyses in which repeated passes over large datasets are needed, requiring fast turnaround times; and (4) distributed authorization and identity management systems, enabling single sign-on access to data distributed across many sites.

Proposed infrastructure software solutions should consider and address the advantages of closely

integrating relevant components of Grid middleware, such as are contained in the software stack of the Open Science Grid, as the foundation used by nuclear physics and other science communities. Applications that propose data distribution and processing projects are encouraged to determine the relevance of and possible future migration strategies into existing infrastructures, and to consider integrated solutions and designs with capacities that would seamlessly include Grid and Clouds computing resources, or help to transparently bridge between the two worlds Clouds and Grids.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

b. Software-Driven Network Architectures for Data Acquisition

Modern data acquisition systems are becoming more heterogeneous and distributed. This presents several new challenges, and existing Supervisory Control And Data Acquisition (SCADA) systems may no longer be applicable to these new large, dynamic, loosely-coupled systems with increased reliability requirements and high data rates. The building blocks of data acquisition system are digitizers, either flash digitizers, or integrating digitizers of time, pulse height or charge. These elements are required to convert detector signals into a digital form in real time. The data from each detector element is labeled with a precisely synchronized time, and transmitted to buffers. The total charge, the number of coincident elements, or other information summaries are used to determine whether something interesting has happened, which constitutes a trigger. If justified by the trigger, the data from these elements are assembled into a time-correlated event for later analysis, a process called Event Building. At present, these elements are typically connected by buses (VME, cPCI), custom interconnects, or serial connections (USB).

For physics experiments at facilities such as RHIC, there is an increasing need for real-time decision making processing such as error correction and recovery, as well as real-time quality control. Data collection and device control would benefit greatly from scalable and versatile control systems. As the number of channels increases, control systems based on EPICS and archiver systems cannot provide the truly distributed and scalable infrastructures needed by remote control rooms. One might instead consider a message queueing paradigm as a possible architecture for meta-data collection.

In certain FRIB experiments, low event rates of 1 to 10 kevents/sec are anticipated, with dense data streams from FADC-based detector systems. The large latencies possible in highly buffered flash ADC architectures can be used to advantage in the design of the architecture. An interesting possibility regarding the next generation of data acquisition systems is that they may ultimately be composed of separate ADCs for each detector element, connected by commercial network or serial technology. Implementation of this distributed data acquisition over commercially available network technologies such as Ethernet or Infiniband will require additional development. One may for example develop a software architecture for a system that works efficiently given available network bandwidth and latencies. Desirable features of this architecture will be to (1) synchronize time across all channels to sufficient precision to support Flash Analog-to-Digital Converter (FADC) clock synchronization (perhaps 10nsec or better), and to support trigger formation and event building (at least 100nsec or better); (2) determine a global trigger from information transmitted by the individual components; (3) notify the elements of a successful trigger, in order to locally store the current information; (4) collect event data from the individual elements to be assembled into events; and (5) develop software tools to validate the synchronization, triggering, and event building during normal operation. Time synchronization is critical to the success of this architecture, as is the concurrent validation of synchronization. This architecture and its

implementation could form the basis of a standard for next-generation data acquisition in nuclear physics, particularly at FRIB. It could be made available for integrating custom front end electronics, and could also be integrated with various ADC and TDC components to form complete commercial solutions. It would be inherently scalable, from small, early test stands of a single computer with an appropriate network card, to large complex detectors.

Applications are invited in the following areas; 1) the development of data acquisition system and control systems above and beyond the classic SCADA architecture; 2) soft core FPGA module(s) to implement the network protocol for Ethernet and/or Infiniband, able to drive existing and emerging commercial network chips, with sufficient buffering to support data aggregation using a commercial network switch, and with sufficient speed to drive 40 Gb/sec network links; 3) time distribution protocols and hardware to support fine-grained time tagging of each network packet for later correlation and event or frame assembly, again with FPGA integration, and possibly exploiting the commercial network for some aspects of tagging.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

c. Heterogeneous Concurrent Computing

Computationally demanding theory calculations as well as detector simulations and data analysis tasks can be significantly accelerated through the use of general purpose Graphics Processing Units (GPUs). The ability to exploit these graphics accelerators is constrained by the effort required to port the software to the GPU environment. More capable cross compilation or source-to-source translation tools are needed that are able to convert very complicated templatized C++ code and into high performance codes for heterogenous architectures.

Early work by the USQCD (US Quantum Chromo Dynamics) collaboration has demonstrated the power of clusters of GPUs in Lattice QCD calculations. This early work was workforce intensive, but yielded a large return on investment through the hand optimization of critical numerical kernels, achieving performance gains of up to 60x with 4 GPUs. Utilizing High Performance Computing (HPC) and Leadership Computing Facilities (LCFs) is of growing relevance and importance to experimental NP as well. NP codes written or rewritten to have the concurrency needed to perform well on prevalent and emerging multi- and many-core architectures can potentially utilize HPC effectively. Experiments are increasingly invited and encouraged to use such facilities, and DOE is assessing the needs of computationally demanding experimental activities such as data analysis, detector simulation, and error estimation in projecting their future computing requirements. Tools and technologies that can facilitate efficient use of HPCs and LCFs for the applications and data-intensive workflows characteristic of experimental NP are in the scope of this subtopic.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the general description at the begining of this topic.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov.

References: Subtopic a:

1. For technical specifications in Large Scale Data Processing and Distribution contact Dr. Jerome Lauret at Brookhaven National Laboratory (jlauret@bnl.gov).

References: Subtopic b:

1. For technical specifications in Software-driven Network Architectures contact Dr. Robert Varner at Oak Ridge National Laboratory (varnerrl@ornl.gov).

2. For technical specifications in Software-driven Network Architectures related to RHIC contact Dr. Jerome Lauret at Brookhaven National Laboratory (jlauret@bnl.gov)

References: Subtopic c:

1. For more specifications on heterogeneous computing described above contact Dr. Chip Watson at Jefferson Lab (watson@jlab.org).

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22. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The DOE Office of Nuclear Physics seeks new developments in detector instrumentation electronics with significantly improved energy, position, timing resolution, sensitivity, rate capability, stability, dynamic range,

durability, pulse-shape discrimination capability, and background suppression. Of particular interest are innovative readout electronics for use with the nuclear physics detectors described in Topic 24 (Nuclear Instrumentation, Detection Systems, and Techniques).

All grant applications must explicitly show relevance to the DOE nuclear physics program. Additionally, applications must be informed by prior art in nuclear physics applications, commercially available products and emerging technologies A proposal based on incremental improvements or little innovations, in the right context, can have an enormous impact or value. Such a proposal must be convincing, otherwise it will be considered as being non-responsive.

Grant applications are sought only in the following subtopics:

a. Advances in Digital and High-Density Analog Electronics

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

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

b. Circuits

Grant applications are sought to develop application-specific integrated circuits (ASICs), as well as circuits (including firmware) and systems, for rapidly processing data from highly-segmented, position-sensitive germanium detectors (pixel sizes in the range of 1 mm^2 to 1 cm^2) and from particle detectors (e.g., gas detectors, scintillation counters, silicon drift chambers, silicon pixel and strip detectors, silicon photomultipliers (SiPMs), particle calorimeters, and Cherenkov counters) used in nuclear physics experiments. Areas of specific interest include (1) low-noise preamplifiers, low-noise filters, peak sensors, timing sensors, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) front-end, digitizing, and multiplexing circuits operating in cryogenic environment, to allow for reduction of noise, power, and number of feedthroughs in highly segmented germanium detectors and noble liquid Time Projection Chambers (TPCs); (3) readout electronics for solid-state pixelated detectors, including interconnection technologies, charge sharing processing and correction circuits (pixel pitch below 250 µm); (4) circuits for high dynamic range, and (5) systems on chip that embody low-noise front-end circuits, analog-to-digital converters, extensive digital signal processing capability tailored to the application, and standard digital interfaces and protocols for compatibility with commercial devices. These circuits should be low-power; low-cost; high-density; programmable to the possible extent; easy to use with commercial auxiliary electronics; compact; and efficiently packaged for multi-channel devices. Also of interest are the following high performance detector readouts:

- Multi-channel Time to Digital Conversion front end ASIC (conventional and radiation hard) for picosecond measurement resolution, over a wide timing range (~1-10 ⍰s).
- Flash ADC using CMOS or superconducting electronics with sampling frequency greater than 50 GHz and sampling depth of 1024-4096 (10-12 bits).

Grant applications are sought for microelectronics beyond the current state-of-art that specifically target low-noise amplification, digitization and smart on-chip processing (triggering, neighboring, sparsification, data reduction) of sensor/detector signals, and that are suitable for next generation detectors. The microelectronics and associated interconnections must be lightweight and have low power dissipation.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

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

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

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

d. Next Generation Pixel Sensors

Active Pixel Sensors (APS) in CMOS (complementary metal-oxide semiconductor) technology have largely replaced Charge Coupled Devices as imaging devices and cameras for visible light. Nuclear physics experiments at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and at the Large Hadron Collider (LHC) at CERN have developed and used APS devices as direct conversion minimum ionizing particle detectors. The innermost tracking detector of the STAR experiment at RHIC contains 356 million (21x21x50 □m) APS pixels. Future high luminosity colliders such as the Electron Ion Collider (EIC) plan to operate at luminosities in the range 10^{33}–10^{35} cm^{-2} s^{-1} and will require radiation hard tracking devices placed at radii below 10 cm. Therefore, cost effective alternatives to the present generation high density APS devices will be required. An ambitious goal is to develop extremely thin ~0.1% radiation length detector modules capable of high rate readout. In low energy nuclear physics applications, the bulk silicon substrate is thicker and is used as the active volume. A major advance would be to introduce an electric field into this drift region and to deplete it. This would result in a much shorter collection time and negligible charge dispersion allowing sensitivity to non-minimum ionizing particles, such as MeV-range gamma rays. Grant applications also are sought for the next generation of active pixel sensors, or even strip sensors. Options may include integrated CMOS detectors which combine initial signal processing and data sparsification on a standard CMOS wafer; superconducting large area pixel detectors; novel 2D- and 3D-pixel materials and geometry structure.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

e. Manufacturing and Advanced Interconnection Techniques

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

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

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

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

f. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the general description at the begining of this topic.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov.

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23. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The Nuclear Physics program supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC), with heavy ion beam energies up to 100 GeV/nucleon and polarized proton beam energies up to 255 GeV; technologies associated with RHIC luminosity upgrades; linear accelerators such as the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF); development of devices and/or methods that would be useful in the generation of intense rare isotope beams with the Facility for Rare Isotope Beams (FRIB) under construction at Michigan State University and the development of a future electron-ion collider;. A major focus in all of the above areas is superconducting radio frequency (RF) acceleration and its related technologies. Relevance of applications to nuclear physics must be explicitly described, as discussed in more detail below. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization.

All grant applications must explicitly show relevance to the DOE nuclear physics program. Additionally, applications must be informed by prior art in nuclear physics applications, commercially available products and emerging technologies A proposal based on incremental improvements or little innovations, in the right context, can have an enormous impact or value. Such a proposal must be convincing, otherwise it will be considered as being non-responsive.

Grant applications are sought only in the following subtopics:

a. Materials and Components for Radio Frequency Devices

Grant applications are sought to improve or advance superconducting and room-temperature materials or components for RF devices used in particle accelerators. Areas of interest include (1) peripheral components, for both room temperature and superconducting structures, such as ultra-high vacuum seals, terminations, high reliability radio frequency windows using alternative materials (e.g., sapphire), ceramics that have good dielectric properties such as a loss tangent better than 0.01% at 1 GHz yet exhibits a small dc conductivity to overcome charging by beams or field emission., RF power couplers, high power low-impedance bellows and magnetostrictive or piezoelectric cavity-tuning mechanisms; (2) fast ferroelectric microwave components that control reactive power for fast tuning of cavities or fast control of input power coupling; (3) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (4) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment, which simplify procedures and reduce costs associated with repair and modification; (5) simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 and/or 4.5 K; (6) alternative, and preferably industrial cavity fabrication techniques, such as hydro forming or spinning of seamless SRF cavities; as well as metal forming techniques with the potential for significant cost reductions by simplifying sub-assemblies – e.g., dumbbells and beam tube – and reducing the number of electron beam welds.; and (7) novel SRF linac mechanical support structures with low thermal conductivity and high vibration isolation and strength.

Grant applications also are sought to develop (1) methods for manufacturing superconducting radio frequency (SRF) accelerating structures with $Q_0>3x10^{10}$ at 2.0 K, or with correspondingly lower Q's at higher temperatures such as 4.5 K; and (2) advanced fabrication methods for SRF cavities of various

geometries (including elliptical, quarter, half wave resonators and crab cavities) to reduce production costs.

Grant applications are also sought to develop advanced diagnostic techniques for SRF cavities/resonators, including new methods of temperature mapping, magnetic flux monitoring, optical inspection and second sound quench detections that will lead to better understanding of the cavity quality factors and quench limits.

Grant applications are also sought to develop new concepts of dressed SRF cavities (SRF cavities equipped with He vessels and tuners) with improved mechanical properties to mitigate He pressure fluctuations, microphonics and Lorentz force detuning.

Grant applications also are sought to develop (1) improved superconducting materials or processes applied to such material that have lower RF losses, operate at higher temperatures, and/or have higher RF critical fields than sheet niobium. Approaches of interest involving atomic layer deposition (ALD) synthesis should identify appropriate precursors and create high quality, NbN, Nb_3Sn, or MgB_2 films with anti-diffusion dielectric overlayers; and (2) techniques to create a layer of niobium on the interior of a copper elliptical cavity, such as by energetic ion deposition, so that the resulting 700-1500 MHz structures have $Q_0 > 1 \times 10^{10}$ at 2 K at operational fields. Demonstration of deposition should be on an actual RF cavity surface, *e.g.*, elliptical, or another cavity surfaces, such as a quarter or crab geometry.

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

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

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

b. Radio Frequency Power Sources

Grant applications are sought to develop designs and hardware for 5-20 kW continuous wave (cw) power sources at distinct frequencies in the range of 50-1500 MHz. Examples of candidate technologies include: solid-state devices, multi-cavity klystrons, tunable/phase stabilized magnetron, Inductive-Output Tubes (IOTs), or hybrids of those technologies. Emphasis is desirable on reduced power consumption, bandwidth, ease of manufacture, mitigation of risk with RF Device obsolescence and enhanced reliability measures. Grant applications also are sought to develop computer software for the design or modeling of any of these devices; such software should be able to faithfully model the complex shapes with full self-

consistency. Software that integrates multiple effects, such as electromagnetic and wall heating is of particular interest.

Grant applications also are sought for a microwave power device, klystron, IOT, tunable/phase stabilized magnetron or solid state amplifiers, especially class F devices, offering improved efficiency (>70%) while delivering up to 12.5 kW, 50 kW or 500 kW CW at 952.6 MHz. The device must provide a high degree of backwards compatibility, both in size and voltage requirements, to allow its use as a replacement for the klystron (model VKL7811) presently used at TJNAF, while providing significant energy savings.

Grant applications are sought for highly efficient 844 MHz RF amplifiers capable of producing in excess of 500 kW CW for the purpose of powering super-conducting accelerator cavities.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

c. Design and Operation of Radio Frequency Beam Acceleration Systems

Grant applications are sought for the design, fabrication, and operation of radio frequency accelerating structures and systems for electrons, protons, and light- and heavy-ion particle accelerators. Areas of interest include (1) continuous wave (cw) structures, both superconducting and non-superconducting, for the acceleration of beams in the velocity regime between 0.001 and 0.03 times the velocity of light, and with charge-to-mass ratios between 1/6 and 1/240; (2) superconducting RF accelerating structures appropriate for rare isotope beam accelerator drivers, for particles with speeds in the range of 0.02-0.8 times the speed of light; (3) innovative techniques for field control of ion acceleration structures (0.1º or less of phase and 0.1% amplitude) and electron acceleration structures (0.1º of phase and 0.01% amplitude) in the presence of 10-100 Hz variations of the structures' resonant frequencies (0.1-1.5 GHz); (4) multi-cell, superconducting, 0.4-1.5 GHz accelerating structures that have sufficient higher-order mode damping, for use in energy-recovering linac-based devices with ~1 A of electron beam; (5) methods for preserving beam quality by damping beam-break-up effects in the presence of otherwise unacceptably-large, higher-order cavity modes – one example of which would be a very high bandwidth feedback system; (6) development of tunable (up to 10^{-4}) superconducting RF cavities for acceleration and/or storage of relativistic heavy ions; and (7) development of rapidly tunable RF systems for applications such as non-scaling fixed-field alternating gradient accelerators (FFAG) and rapid cycling synchrotrons, either for providing high power proton beams.

More specifically, RF cavities with high gain in voltage >30 kV and fast frequency switching are of interest for applications in fast acceleration of non-relativistic protons or ions with $0.1 < v/c < 0.75$. The goal is to create higher Q cavities where the frequency between two cavities can vary up to 25%.

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

A high-integrated-voltage SRF cw crab crossing cavity is also of interest. Therefore, grant applications are sought for (1) designs, computer-modeling, and hardware development for an SRF crab crossing cavity with 0.4 to 1.5 GHz frequency and 3 to 50 MV integrated voltage; and (2) beam dynamics simulations of an interaction region with crab crossing. One example of candidate technologies would be a multi-cell SRF deflecting cavity.

Finally, grant applications also are sought to develop and demonstrate low level RF system control algorithms or control hardware that provide a robust and adaptive environment suitable for any accelerator RF system. Of special interest are approaches that address the particular challenges of superconducting RF systems, but room temperature systems are of interest as well.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

d. Particle Beam Sources and Techniques

Grant applications are sought to develop (1) particle beam ion sources and/or associated components with improved intensity, emittance, and range of species; (2) methods and/or devices for reducing the emittance of relativistic ion beams – such as coherent electron cooling, electron bunched-beam cooling, and electron or optical-stochastic cooling; (3) methods and devices to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers, electron-beam ionizers, or special stripping techniques); (4) methods and /or devices for improving emission capabilities of photocathode sources, such as improving charge lifetime, bunch charge, average current, emittance, or energy spread; (5) techniques for in situ coating of elliptical and other surface contour RF cavities and long beam pipes with thick superconducting films; (6) novel methods for in situ surface cleaning (scrubbing) of ultrahigh vacuum long narrow tubes and elliptical cavities to reduce secondary electron yield and outgassing; (7) novel, robust coatings to passivate conductance limited beam pipe for UHV operation to reduce thermal and stimulated outgassing; (8) high brightness electron beam sources utilizing continuous wave (cw) superconducting RF cavities with integral photocathodes operating at high acceleration gradients; (9) techniques and devices for measuring RF resistivity of cryogenically cooled coated tubes; and (10) CW superconducting or normal-conducting RF cavity(s) that integrate with photocathode or field emitting cathodes such as micro-tips or carbon nanotubes.

Accelerator techniques for an energy recovery linac (ERL) and/or a circulator ring (CR) based electron cooling facility for cooling medium to high energy bunched proton or ion beams are of high interest for next generation colliders for nuclear physics experiments**.** Therefore, grant applications are sought for (1) design, modeling and proto-type development for a magnetized electron source/injector with a high bunch charge (up to 2 nC), up to 1 ns bunch length, high average current (above 200 mA) and high bunch repetition rate (20 to 500 MHz); (2) designs, modeling, and hardware and component development for a fast beam-switching kicker with 0.5 ns duration and 10 to 20 kW power in the range of 5-50 MHz repetition rate; (3) optics designs and tracking simulations of beam systems for ERLs and CRs, with energy range from 5 to 130 MeV; (4) designs, modeling, and hardware and component development for understanding the effects of passage through targets and solenoidal magnetic fields on energy recovery, and beam characteristics, (5) transporting and matching magnetized beams with superconducting solenoids in cooling channels; (6) study of synchrotron radiation and its impact on beam dynamics in ERLs and CRs; and (7) development of new concepts for high-energy, high-power electron beam dumps that minimize activation of surrounding structures. Examples of candidate technologies include photocathode

or thermionic electron guns with a DC or RF accelerating structure; SRF deflecting cavity, pulse compression techniques, and beam-based kicker. Grant applications also are sought to develop computer software for the design, modeling and simulating any of these devices and beam transport systems.

Grant applications are sought to develop beam absorbers for energy-recovery linac driven medical isotope facilities. In such facilities an energy-recovering electron beam interacts with a thin high-Z target. After interaction with the thin target, the beam halo generated must be deposited in a controlled way and absorbed downstream of the target but before substantial bending for energy recovery. High efficiency in beam absorption leads to higher electron beam current and to higher possible overall production rates in the facility.

Grant applications are sought for the development of alkali-antimonide photocathodes that exhibit high quantum efficiency and robust long-lifetime operation while delivering high average current beams (milliamperes) when used inside dc high voltage or rf photoguns. These cathodes should be optimized to achieve high electron beam brightness, ideally in the presence of strong electric fields. We envision a commercial product line of photocathodes grown on substrates compatible with load locked gun designs used at a variety of national laboratories.

Lastly, grant applications are sought to develop software that adds significantly to the state-of-the-art in the simulation of beam physics. Areas of interest include (1) electron cooling, including software product for start to end simulations of coherent electron cooling, including both microbunching and FEL concepts, (2) intra-beam and interbeam scattering, (3) spin dynamics, (4) polarized beam generation including modeling of cathode geometries for high current polarized electron sources, (5) generating and transporting polarized electron beam, (6) beam dynamics, transport and instabilities, (7) electron or plasma discharge in vacuum under the influence of charged beams, (8) simulation of space-charge tune shift and tune spread in stored ion beams, (9) beam-beam effects in colliders; and (9) non-relativistic space charge and its influence on ring dynamics. The software should use modern best practices for software design, should run on multiple platforms, and should run in both serial and parallel configurations. Such product should be easy to use and provide visualization. There is particular interest in porting accelerator modeling codes to the GPU, Xeon Phi, and other emerging architectures. Grant applications also are sought to develop graphical user interfaces for problem definition and setup.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

e. Polarized Beam Sources and Polarimeters

With respect to polarized sources, grant applications are sought to develop (1) polarized hydrogen and deuterium (H-/D-) ^{3}He sources and/or associated components with polarization above 90%; (2) cw polarized electron sources and/or associated components delivering beams of ~50 mA, with longitudinal polarization greater than 80%; (3) devices, systems, and sub-systems for producing variable-helicity beams of electrons with polarizations greater than 80% and currents > 200 microamps , that have very small helicity-correlated changes in beam intensity, position, angle, and emittance.

Grant applications also are sought to develop (1) methods to improve high voltage stand-off and reduce field emission from high voltage electrodes, compatible with ultra-high-vacuum environments; (2) wavelength-tunable (700 to 850 nm) mode-locked lasers, with pulse repetition rate between 0.5 and 3

GHz and average output power >10 W; and (3) a cost-effective means to obtain and measure vacuum below 10^{-12} Torr.

Grant applications also are sought for (1) advanced software and hardware to facilitate the manipulation and optimized control of the spin of polarized beams; (2) advanced beam diagnostic concepts, including new beam polarimeters and polarimeter targets and fast reversal of the spin of stored, polarized beams; (3) absolute polarimeters for spin polarized ^{3}He beams with energies up to 160 GeV/nucleon (4) novel concepts for producing polarizing particles of interest to nuclear physics research, including electrons, positrons, protons, deuterons, and ^{3}He; and (5) credible sophisticated computer software for tracking the spin of polarized particles in storage rings and colliders.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

f. Charge Strippers for Heavy Ion Accelerators

The following simulation studies are of interest: (1) simulation of the interaction of an intense heavy ion beam with the media used in charge strippers; (2) simulation of the effect of the heavy ion beam on a liquid lithium film used as a charge stripper; and (3) simulation of a He gas stripper with counter flows perpendicular to the heavy ion beam in order to study the heating effect and density variations effects on energy spread. Study of the film stability with high power density deposition is also of interest.
Thin foils are also desirable as windows for gas targets and as photon taggers used in conjunction with Megawatt electron beams for fundamental nuclear physics experiments.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

g. Rare Isotope Beam Production Technology

Grant applications are sought to develop (1) ion sources for radioactive beams, (2) techniques for secondary radioactive beam collection, charge equilibration, and cooling; (3) technology for stopping energetic radioactive ions in helium gas and extracting them efficiently as high-quality low-energy ion beams; (4) advanced parallel-computing simulation techniques for the optimization of both normal- and super-conducting accelerating structures for the Facility for Rare Isotope Beams (FRIB), and (5) High-rate (~10^7 pps) position, angle and timing tracking detectors for fast heavy ion beams (50-250 MeV/u)...

Grant applications also are sought to develop fast-release solid catcher materials. The stopping of high-energy (>MeV/u) heavy-ion reaction products in solid catchers is important for realizing high-intensity low-energy beams of certain elements and for the parasitic use of rare isotopes produced by projectile fragmentation. The development of suitable high-temperature materials to achieve fast release of the stopped rare isotopes as atomic or single-species molecular vapor is required

Grant applications also are sought to develop techniques for efficient rare isotope extraction from water. Water-filled beam dumps or reaction product catchers, considered in the context of high-power rare isotope beam production, could provide a source for the harvesting heavy-ion reaction products stopped in the water.

Grant applications also are sought to develop techniques for the charge breeding of rare isotopes in Electron Beam Ion Sources or Traps (EBIS/T) prior to reacceleration. High breeding efficiencies in single charge states and short breeding times are required. In order to be able to optimize these values, simulation tools will be needed that realistically describe electron-ion interaction and ion cooling mechanisms and use accurate electric and magnetic field models. Also high performance electron guns with well-behaved beam compression into the magnetic field of the EBIS/T will be required. The electron guns will have to be optimized for high perveance and multi-Ampere electron current output in order to optimize ion capacity, ion beam acceptance and breeding times.

Grant applications are sought for development of radiation tolerant or radiation resistant multipole inserts in large-aperture superconducting quadrupoles used in fragment separators. Sextupole and octupole coils with multipole fields of up to 0.4 T are required to operate in a 2-T quadrupole field. Minimum cold mass and all-inorganic construction are requirements that may be partially met with High Temperature Superconducting (HTS) coils or conventional superconductors with non-standard insulation.

Grant applications are sought for development of radiation resistant thermal isolation systems for superconducting magnets. Support links connecting room temperature with the liquid helium structure have to support large magnetic forces, but at the same time have low thermal conductivities to limit heat input. Typically, all-metal links have ten to twenty times higher heat leaks than composite structures. Composites are, however, hundreds or thousands of times more sensitive to radiation damage than metals and so cannot be used in the high-radiation environment surrounding the production target or beam dump areas of high-power heavy ion accelerators. Given the high cost of cryogenic refrigeration, development of radiation resistant, high-performance support links is very desirable.

Lastly, grant applications are sought to develop advanced and innovative approaches to the construction of large aperture superconducting and/or room temperature magnets and/or associated components, for use in fragment separators and magnetic spectrographs at rare isotope beam accelerator facilities. Grant applications also are sought for special designs that are applicable for use in high radiation areas.

(Additional needs for high-radiation applications can be found in subtopic f “Technology for High Radiation environments” of Topic 24, Nuclear Physics Detection Systems, Instrumentation and Techniques.)

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

h. Accelerator Control and Diagnostics

Grant applications are sought to develop (1) advanced beam diagnostics concepts and devices that provide high speed computer-compatible measurement and real-time monitoring and readout of particle beam intensity, position, emittance, polarization, luminosity, momentum profile, time of arrival, and energy (including such advanced methods as neural networks or expert systems such as those employing genetic algorithms, and techniques that are nondestructive to the beams being monitored); (2) beam diagnostic devices that have increased sensitivities through the use of superconducting components (for example, filters based on high T_c superconducting technology or Superconducting Quantum Interference Devices); (3) measurement devices/systems for cw beam currents in the range 0.1 to 100 μA, with very high precision ($<10^{-4}$) and short integration times; (4) beam diagnostics for ion beams with intensities less than 10^7 nuclei/second; (5) non-destructive beam diagnostics for stored proton/ion beams, such as at the RHIC,

and/or for 100 mA class electron beams; (6) devices/systems that measure the emittance of intense (>100kW) cw ion beams, such as those expected at FRIB; (7) beam halo monitor systems for ion beams; (8) instrumentation for electron cloud effect diagnostics and suppression, and (9) new beam diagnostics enabled by non-traditional bulk materials such as diamond, graphene, other thin-film and nano-structured materials.

Grant applications are sought for the development of triggerable, high speed optical and/or IR cameras, with associated MByte-scale digital frame grabbers for investigating time dependent phenomena in accelerator beams. Image capture equipment needs to operate in a high-radiation environment and have a frame capture rate of up to 1 MHz. Imaging system needs to have memory capacity at the level of 1000 frames (10 GByte or higher total memory capacity). The cameras will be used for high-speed analysis of optical transition or optical diffraction radiation data.

Grant applications are sought for developing point of delivery beam bunch length monitors for the Jefferson Lab CEBAF accelerator. Beam energies are from 6-12 GeV and bending magnets are available to produce synchrotron radiation. Non-invasive monitoring is preferred. 500 MHz beam currents are typically above 5 uA and bunch lengths are typically below 30 microns rms.

Grant applications also are sought for “intelligent” software and hardware to facilitate the improved control and optimization of charged particle accelerators and associated components for nuclear physics research. Areas of interest include the development of (1) generic solutions to problems with respect to the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning; (2) systems for predicting insipient failure of accelerator components, through the monitoring/cataloging/scanning of real-time or logged signals; and (3) devices that can perform direct 12-14 bit digitization of signals at 0.5-2 GHz and that have bandwidths of 100+ kHz.

Grant applications are sought to develop wire scanners for profile measurement of high intensity charged particle beams. The application of new materials that may survive exposure to such beams is especially encouraged. For example, BNNT fiber is known for its high temperature stability but has not been used in an accelerator application. The resultant fiber should have a diameter smaller than 50 microns and be sufficiently stable to be self-supported over a gap of 2 centimeters. Carbon fiber wires and Tungsten wires do not survive high intensity beams similar to CEBAF, SLAC LCLS and/or CERN LHC.

Grant applications are sought to develop beam diagnostic instrumentation based on High Temperature Superconducting materials. Examples include low noise non-invasive beam monitors for current, position, and polarization of charged particle beams in accelerators. The instrumentation should be capable of measuring sub-nano amp beam properties with msec or better integration times.

Control System Studio (CS-Studio) is an Eclipse-based collection of tools to monitor and operate large scale control systems, such as the ones in the accelerator community. It is a product of the collaboration between Facility for Rare Isotope Beams, Spallation Neutron Source, and National Synchrotron Light Source II. One of the primary concerns with CS-Studio remains its reliance on the Standard Widget Toolkit (SWT), used by the Eclipse Rich Client Platform which offers a look and feel similar to the running platform. Unfortunately this approach has also resulted in SWT having a rather limited widget set whose functionality and ease of use are significantly compromised by the need to be supported on all platforms. JavaFX represents a potential replacement for SWT in CS-Studio. As part of the JDK version 7, it comes with complex widgets and interactions. Grant applications are sought to develop: (1) graphical editor

framework to enable data visualization and creation of synoptic displays. (2) runtime environment - an extendable framework to process and display real time data that supports control system protocols (EPICS v3, v4), web services, and integration patterns. The model would remove the close coupling with specific technologies like Eclipse's Graphical Editing Framework, while utilizing JavaFX and web-related technologies.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

i. Magnet Development for Future Electron-Ion Colliders (EIC)

One of the options under consideration for EIC is based on the Energy Recovery Linac (ERL) architecture for the electron beam. The ERL requires return passes - beam lines for electrons to be brought back to the linac during acceleration and deceleration. After collisions with ions the highest energy electrons are decelerated by going through the linac with an opposite RF voltage. The beam lines could be built of permanent magnets to reduce the overall cost. In addition if the magnets are designed for use in a Non-Scaling Fixed Field Alternating Gradient structure they can transfer multiple energies within the same aperture. Grant applications are sought to (1) manufacture prototype magnets using a permanent magnetic material. They can be either quadrupoles or focusing/defocusing combined function magnets. The same type of structure could be used for the proton cancer therapy gantries where the 30-250 MeV protons would be delivered under different angles to the patients. There is also a strong interest in the proton cancer therapy for this type of gantry as it simplifies the treatment due to the fixed magnetic field and due to reduction of the magnet size and weight.

A full utilization of the discovery potential of a next-generation electron-ion collider requires a full-acceptance detection system that can provide detection of reaction products scattered at small angles with respect to the incident beams over a wide momentum range. Grant applications are sought for design, modeling and hardware development of the special magnets for such a detection system. Magnets of interest include (1) radiation-resistant superconducting (≥ 2 T pole-tip field) septum dipole with electronically adjustable field orientation (+/- 100 mrad); (2) radiation-resistant high-field (≥ 9 T pole-tip field), large-aperture (≥ 20 cm radius) quadrupole; (3) radiation-resistant superconducting (≥ 6 T pole-tip field) large-aperture (≥ 20 cm radius) small-yoke-thickness (≤ 14 cm OD-ID) quadrupole; (4) radiation-resistant super-conducting (≥ 6 T pole-tip field, ~3 cm IR) combined-function magnet with quadrupole and independently adjustable horizontal and vertical dipole field components.

High-performance, low-cost, low-energy-consumption magnets and systems are of great importance for feasibility of future accelerator facilities. Grant applications are sought for design, simulation and prototyping of such magnets and systems allowing for peak fields of greater than 3 T, field quality better than ~10^-4 within ~3 cm aperture radius, high ramp rate of greater than 1 T/s, lower power consumption than conventional room-temperature magnets, and significantly lower cost than conventional cos-theta superconducting magnets. Examples include superferric dipoles and/or quadrupoles, power supplies, cryogenic systems, manufacturing techniques, etc. applicable in future large-scale accelerator projects such as an electron-ion collider.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

j. Accelerator Systems Associated with the Capability to Deliver Heavy-Ion Beams to Multiple Users

At present, ATLAS is the only U.S. national user facility for low-energy nuclear physics. There is a concept to expand the scientific reach of ATLAS by providing different stable and/or radioactive beams simultaneously to 2 or 3 physics experiments. There is a motivation for the simultaneous production, acceleration and distribution of stable and radioactive ion beams in a superconducting linac. Particular interest is in switching devices for separation of ~8-25 MeV/u heavy ion beams. One of the options could be a pulsed magnet capable to operate with short (~0.25 ms) rise/fall time, ~1-2% duty factor and 30 Hz repetition rate.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

k. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact Manouchehr.farkhondeh@science.doe.gov.

References: Subtopic a:

1. For questions related to items (1) through (7) in the first paragraph of this subtopic, contact Dr. Robert Rimmer at Thomas Jefferson National Accelerator Facility (rarimmer@jlab.org) or Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov).

2. For all other specification questions, contact Dr. Charles Reece at Thomas Jefferson National Accelerator Facility (reece@jlab.org) or Dr. Sergey Belomestnykh at Brookhaven National Laboratory (sbelomestnykh@bnl.gov).

References: Subtopic b:

1. For further specifications on power sources, contact Dr. Robert Rimmer at Thomas Jefferson National Accelerator Facility (TJNAF) (rarimmer@jlab.org), Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov), and Dan Morris at Facility for Rare Isotope Beams (FRIB) (morrisd@nscl.msu.edu).

2. For more detail on technical specification of TJNAF klystron replacement, contact Rick Nelson at Thomas Jefferson Laboratory (nelson@jlab.org). For more details on technical specifications of BNL RF devices, contact Alex Zaltsman (zaltsman@bnl.gov).

References: Subtopic c:

1. For further specifications on fast frequency switching rf cavities contact Dr. Dejan Trbojevic at Brookhaven National Laboratory (trbojevic@bnl.gov).

2. For questions related to software design and modeling, contact Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov) or Dr. Sergey Belomestnykh at Brookhaven National Laboratory sbelomestnykh@bnl.gov.

3. For questions or further specifications on SRF deflecting cavities, contact Drs. Yaroslav Derbenev, Geoffrey Krafft or Yuhong Zhang at Thomas Jefferson National Accelerator Facility (derbenev@jlab.org, krafft@jlab.org, yzhang@jlab.org), or Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov) or Dr. Sergey Belomestnykh at Brookhaven National Laboratory (sbelomestnykh@bnl.gov).

References: Subtopic d:

1. For questions and further specifications on design, modeling and hardware development of full acceptance magnets for EIC, contact Dr. Yuhong Zhang at Thomas Jefferson National Accelerator Facility (yzhang@jlab.org).

2. For further information related to coherent electron cooling, please contact Dr. Vladimir Litvinenko at Brookhaven National Laboratory (vl@bnl.gov).

3. For further specifications to develop beam absorbers for energy-recovery-linac contact Dr. Geoffrey Krafft (krafft@jlab.org).

4. For further information about alkali-antimonide photocathodes please contact Carlos Hernandez-Garcia (chgarcia@jlab.org), John Smedley (smedley@bnl.gov), or Triveni Rao (triveni@bnl.gov).

5. For additional information on accelerator design for: Multi-pass ERL's and Ion complex components for EIC contact Dr. Alex Bogacz (bogacz@jlab.org).

6. For further questions to develop software for state-of-the-art in the simulation of beam physics contact Dr. Ilan Ben-Zvi at Brookhaven National Laboratory (benzvi@bnl.gov) and Yves Roblin at Thomas Jefferson National Accelerator Facility (roblin@jlab.org).

7. For further questions on items (5) and (6) “in situ coating”, contact Dr. Ady Hershcovitch at Brookhaven National Laboratory (hershcovitch@bnl.gov).

References: Subtopic e:

1. For further specifications on polarized electron sources, contact Dr. Matthew Poelker at Thomas Jefferson National Accelerator Facility (poelker@jlab.org). For questions on polarized ion sources contact Dr. Anatoli Zelenski at Brookhaven National Laboratory (zelenski@bnl.gov).

References: Subtopic f:

1. For further technical specifications contact Dr. Felix Marti (marti@frib.msu.edu) at Facility for Rare Isotope Beams (FRIB).

References: Subtopic g:

1. For further specifications on rare isotope beam technology contact the following: fast-release solid catcher materials: Dr. Dave Morrissey, NSCL/MSU (morrissey@nscl.msu.edu). For charge breeding (EBIS/T): Dr. Stefan Schwarz NSCL//MSU (schwarz@nscl.msu.edu). For radiation resistant superconducting quadrupoles: Dr. Al Zeller, FRIB/MSU (zeller@frib.msu.edu). For innovative approaches to the construction of large aperture magnets: Interested parties should contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu).

References: Subtopic h:

1. For further specifications on triggerable, high speed frame grabber cameras or bunch length monitors contact Dr. Geoffrey Krafft at Thomas Jefferson National Accelerator Facility (krafft@jlab.org).

2. For further specifications on wire scanners for high intensity profile measurements contact Dr. Hari Areti at Thomas Jefferson National Accelerator Facility (areti@jlab.org).

3. For further specifications on beam diagnostics based on high T_c materials contact Dr. Hari Areti (areti@jlab.org) or Dr. Geoffrey Krafft (krafft@jlab.org) at Thomas Jefferson National Accelerator Facility.

4. For further specifications on Control System Studio graphical editor framework and runtime environment contact Eric Berryman (berryman@frib.msu.edu) at Facility for Rare Isotope Beams (FRIB).

5. For further specifications and information on New beam diagnostics enabled by non-traditional bulk materials (item 9 in first paragraph) contact Dr. Zhehui (Jeff) Wang at Los Alamos National Laboratory (zwang@lanl.gov),

References: Subtopic i:

1. Persons to contact: Dr. Dejan Trbojevic at Brookhaven National Laboratory -BNL (dejan@bnl.gov), and Dr. Vadim Ptitsyn – BNL (vadimp@bnl.gov),and Dr. Vasiliy Morozov, Thomas Jefferson National Accelerator Facility (morozov@jlab.org).

References: Subtopic j:

1. Persons to contact: Drs. Peter Ostroumov or Brahim Mustapha at Argonne National Laboratory –ANL (ostroumov@phy.anl.gov) or (brahim@anl.gov).

References:

1. NP SBIR/STTR Topic Associate for Accelerator Technology: Michelle Shinn (Michelle.Shinn@science.doe.gov).

2. (FRIB) Facility for Rare Isotope Beams, Michigan State University, Webpage. (http://frib.msu.edu/)

3. Duggan, J.L., and Morgan, I.L., 2003, *Application of Accelerators in Research and Industry: 17th International Conference on the Application of Accelerators in Research and Industry*, Proceedings of the 17th International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 12-16, 2002, New York: American Institute of Physics. (ISBN: 978-0735401495) (http://www.amazon.com/Application-Accelerators-Research-Industry-Instrumentations/dp/0735401497/ref=sr_1_1?ie=UTF8&qid=1252008928&sr=8-1).

4. Champion, M., et al., 2003, *The Spallation Neutron Source Accelerator Low Level RF Control System*, Proceedings of 2003 Particle Accelerator Conference, Portland, OR., pp. 3377. (http://accelconf.web.cern.ch/accelconf/p03/INDEX.HTM).

5. Angoletta, M., 2006, *Digital Low Level RF*, Proceedings of the European Particle Accel. Conf., Geneva, WEXPA03. (https://accelconf.web.cern.ch/accelconf/e06/PAPERS/WEXPA03.PDF)

6. 7th SRF Materials Workshop, Jefferson Lab, July 16-17, 2012. (https://www.jlab.org/indico/conferenceDisplay.py?confId=20)

7. 2014, Proceedings of the 6th International Workshop on Thin Films and New Ideas for RF Superconductivity, INFN-Legnaro. (http://www.surfacetreatments.it/thinfilms-2014/)

8. Department of Energy, 2015, *Labs at-a-glance: Thomas Jefferson National Accelerator Facility*. (http://science.energy.gov/laboratories/thomas-jefferson-national-accelerator-facility/)

9. U.S. DOE Brookhaven National Laboratory, 2007, eRHIC: The Electron-Ion-Collider (EIC) Project Webpage. (http://www.phenix.bnl.gov/WWW/publish/abhay/Home_of_EIC/)

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14. 2014, TESLA Technology Collaboration Meeting, KEK, Dec 2-5. (http://lcdev.kek.jp/LCoffice/OfficeAdmin/TTC14/)

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16. 2015, SRF2015, 17th International Conf. on RF Superconductivity. Whistler Conference Centre, September 13-18. (http://srf2015.triumf.ca)

17. A. Perry, B. Mustapha, P.N. Ostroumov, 2013, Proposal for Simultaneous Acceleration of Stable and Unstable Ions in ATLAS, Proceedings of the NA-PAC-13, Pasadena, CA, p. 306. (http://accelconf.web.cern.ch/accelconf/pac2013/papers/mopma06.pdf)

24. NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

The Office of Nuclear Physics is interested in supporting projects that may lead to advances in detection systems, instrumentation, and techniques for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art at universities and national user facilities, facilities worldwide. A new suite of next-generation detectors will be needed for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade at the Thomas Jefferson National Accelerator Facility (TJNAF), and at the future Facility for Rare Isotope Beams (FRIB) under construction at Michigan State University, and associated with detector and luminosity upgrades at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab, and a possible future Electron-Ion Collider (EIC). Also of interest is technology related to future experiments in fundamental symmetries, such as neutrinoless double-beta decay (DBD) experiments and the measurement of the electric dipole moment of the neutron. In case of DBD experiments, extremely low background and low count rate particle detection are essential. This topic seeks state-of-the-art targets for applications ranging from spin polarized and unpolarized nuclear physics experiments to stripper and production targets required at high-power, advanced, rare isotope beam facilities. Lastly, this topic seeks new and improved techniques and instrumentation to cope with the high radiation environments anticipated for FRIB. All grant applications must explicitly show relevance to the nuclear physics program.

All grant applications must explicitly show relevance to the DOE nuclear physics program. Additionally, applications must be informed by prior art in nuclear physics applications, commercially available products and emerging technologies A proposal based on incremental improvements or little innovations, in the right context, can have an enormous impact or value. Such a proposal must be convincing, otherwise it will be considered as being non-responsive.

Grant applications are sought only in the following subtopics:

a. Advances in Detector and Spectrometer Technology

Nuclear physics research has a need for devices to detect, analyze, and track photons, charged particles, and neutral particles such as neutrons, neutrinos, and single atoms. Grant applications are sought to develop and advance the following types of detectors:

(1) Ultra-violet and optical photon detectors and photosensitive devices:

- Geiger avalanche photodiodes with a response faster than 10ps and area significantly larger and pixelation significantly denser than current commercial offerings;
- Silicon Photomultipliers (SiPMs), in particular radiation-tolerant SiPMs , low radioactivity SiPMs, large area, low noise SiPMs or digital SiPMs with photon detection efficiency, especially in blue and UV wavelengths, and noise significantly improved over current state of the art with the goal of large arrays.
- hybrid photomultiplier devices or devices using new types of large area (>>cm^2) photoemissive materials.

- photon detectors capable of working in a liquid helium environment, noble gas or liquid ionization chambers, and other cryogenic detectors;

(2) Electromagnetic (EM) and hadronic calorimeters including:

- new and innovative calorimeter concepts, new high-density absorber materials, improved absorber packing schemes to achieve a small Moliere radius and short radiation length for electromagnetic calorimetry, new materials and methods for improving calorimeter energy resolution, and cost effective or new manufacturing techniques for producing calorimeter components.
- EM calorimeters capable of handling high rates in an environment with a high background at low energies and high radiation environments. See end references for details.

(3) Systems for detecting the magnetization of polarized nuclei in a magnetic field (e.g., Superconducting Quantum Interference Devices (SQUIDs) or cells with paramagnetic atoms that employ large pickup loops to surround the sample).

(4) Particle identification detectors such as:

- low cost large area MCP type detector with high spatial resolution, high rate capability, radiation tolerance, magnetic field tolerance, and timing resolution of < 10 ps for time-of-flight detectors
- Cherenkov detectors with broad particle identification capabilities over a large momentum range and/or large area that can handle and trigger at high rate in noisy (very high rate, low-energy background) environments; and are magnetic field tolerant;
- low-cost large area pixelated visible light sensor for Aerogel detectors;
- affordable methods for the production of large volumes of high-purity xenon, argon and krypton gas (which would contribute to the development of transition radiation detectors and also would have many applications in X-ray detectors);
- very high resolution (tenths of micrometers spatial resolution and tenths of eV energy resolution) particle detectors or bolometers (including the required thermistors) based on cryogenic semiconductor materials and radio-frequency techniques.
- detector technologies capable of measuring energies of alpha particles and protons with less than 5 keV resolution, thereby allowing spectroscopy experiments using light charged particles to be performed in the same way as spectroscopy experiments using gammas.

(5) Precision detector calibration methods such as

- controllable calibration sources for electrons, gammas, alphas, and neutrons;
- pulsed calibration sources for neutrons, gammas, and electrons;
- precision charged particle beams;
- pulsed UV and optical sources

(6) Spectrometers and innovative magnet designs such as

- development of iron-free magnet systems with tilted crossed solenoid windings and active shielding for a broad variety of superconducting dipoles, which could be used in high-acceptance spectrometers.
- innovative designs for high-resolution particle separators and spectrometers for next-generation rare isotope beam and intense stable beam facilities. Developments of interest include both air-core and iron-dominated superconducting magnets that use either conventional low-

temperature conductors or new medium to high-temperature conductors for magnetic spectrometers, fragment separators, and beam transport systems. Innovative designs such as elliptical aperture multipoles and other combined function magnets are of interest.

- cryogenic systems in the mid-capacity range for use with superconducting spectrometers for nuclear physics. The emphasis is on cryogenic systems with higher capacity, improved efficiency, and reduced maintenance requirements at both low (4-20 K) and intermediate temperatures (50-77 K) relative to the present generation of cryo-coolers.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

b. Development of Novel Gas and Solid-State Detectors

Nuclear physics research has the need for devices to track charged particles, and neutral particles such as neutrons and photons. Items of interests are detectors with high energy resolution for low-energy applications, high precision tracking of different types of particles, and fast triggering capabilities. The subtopic announcements are grouped into solid-state devices and novel gas detectors.

Grant applications are sought to develop novel gamma-ray detectors, including:

1. Position-sensitive photon tracking devices for nuclear structure and astrophysics applications, as well as associated technology for these devices. High-resolution germanium (Ge) capable of determining the position (to within a few millimeters utilizing pulse shape analysis) and energy of individual interactions of gamma-rays (with energies up to several MeV), allowing for the reconstruction of the energy and path of individual gamma-rays using tracking techniques, are of particular interest.
2. Techniques for increasing the volume and/or area, or improving the performance of Ge detectors, or for substantial cost reduction of producing large-mass Ge detectors.
3. Alternative materials, with resolution comparable to germanium, but with higher efficiency and room- temperature operation.

Grant applications are sought to develop advances in the general field of solid-state devices for tracking of charged particles and neutrons, such as silicon drift, strip, and pixel detectors, along with 3D silicon devices. Approaches of interest include:

1. Manufacturing techniques, including interconnection technologies for high granularity, high resolution, light-weight, and radiation-hard solid state devices;
2. Thicker (more than 1.5 mm) segmented silicon charged-particle and x-ray detectors and associated high density, high resolution electronics;
3. Low mass active-pixel sensors with thickness ~ 50 µm and large area Si pixel and strip detectors with thickness < 200 µm.
4. Segmented solid state devices for neutron detection, with integrated electronics.
5. Diamond detector or other radiation hard strip detector with strip size of 500 µm or less and at least 192 strip giving a total length of at least 4.8 cm long.

Grant applications are sought in the general field of micropattern gas detectors. This includes:

1. New developments in micro-channel plates; micro-strip, Gas Electron Multipliers (GEMs), Micromegas and other types of micro-pattern detectors;
2. Commercial and cost effective production of GEM foils or thicker GEM structures;
3. Micro-pattern structures, such as fine meshes used in Micromegas;

4. High-resolution multidimensional readout such as 2D readout planes;
5. Systems and components for large area imaging devices using Micromegas technology associated with the read-out of a high number of channels (typically ~10,000), which requires the development of printed circuit boards that have superior surface quality to minimize gain fluctuations and sparking.

Grant applications are sought for the advancement of more conventional gas tracking detector systems, including drift chambers, pad chambers, time expansion chambers, and time projection chambers such as:

1. Gas-filled tracking detectors such as straw tubes (focusing on automated assembly and wiring techniques), drift tube, proportional, drift, and streamer detectors;
2. Improved gases or gas additives that resist aging, improved detector resolution, decreased flammability and larger, more uniform drift velocity;
3. Application of CCD cameras for optical readout in Time-Projection Chamber or other gaseous chamber detector technologies capable of tracking and measuring low momentum (<100 GeV/c) alpha particle, deuteron and proton with better than 10 keV resolution, thereby allowing tagged fixed-target experiments;
4. New developments for fast, compact TPCs.
5. Gamma-ray detectors capable of making accurate measurements of high intensities (>10^{11} /s) with a precision of 1-2 %, as well as economical gamma-ray beam-profile monitors;
6. Components of segmented bolometers with high-Z material (e.g., W, Ta, Pb) for gamma ray detection with segmentation, capable of handling 100 -1000 gamma rays per second.

Finally, grant applications are sought to develop detector systems for rare isotope beams with focus on:

1. Next-generation, heavy-ion focal plane detectors or detector systems for magnetic spectrometers and recoil separators with high time resolution (< 200ps FWHM), high energy-loss resolution (1-2%), and high total-energy resolution (1-2%).
2. High-rate, position-sensitive particle tracking and timing detectors for heavy-ions, including associated readout electronic and data acquisition systems. Of interest are detectors with single-particle detection capability at a rate of 10^7 particles per second, a timing resolution of better than 0.25 ns, spatial resolution of better than 10 mm (in one direction) and minimal thickness variations (< 0.1 – 0.5 mg/cm^2) over an active area of typically 1 × 20 cm. In addition, a successful design would maintain performance during continuous operation (at 10^7 s^{-1} particle rate) over multiple weeks. Arrays of diamond detectors would be a possible approach.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

c. Technology for Rare Decay and Rare Particle Detection

Grant applications are sought for detectors and techniques to measure very weak or rare event signals in the presence of significant backgrounds. Such detector technologies and analysis techniques are required in searches for rare events (such as double beta decay) and searches for new nuclear isotopes produced at radioactive-beam and high-intensity stable-beam facilities. Rare decay and rare event detectors require large quantities of ultra-clean materials for shielding and targets.

Grant applications are sought to develop:

1. Ultra-low background techniques and materials for supporting, cooling, cabling, connecting and processing signals from high-density arrays of detectors (such as radio-pure signal cabling, signal and high voltage interconnects, vacuum feedthroughs, front-end amplifier FET assemblies and front-end ASICs; radiopurity goals are as low as 1 micro-Becquerel per kg);
2. Ultra-sensitive assay or mass-spectrometry methods for quantifying contaminants in ultra-clean materials;
3. Cost-effective production of large quantities of ultra-pure liquid scintillators;
4. Novel methods capable of distinguishing between interactions of gamma rays and charged particles in detectors;
5. Methods by which the background events in rare event searches, such as those induced by gamma rays or neutrons, can be tagged, reduced, or removed entirely.
6. Novel materials with ultra-low trace contamination of radionuclides and solutions for the construction of ultra-low background detectors. This includes structural and vacuum-compatible materials, hermetic containers and cable feedthroughs.
7. Novel techniques for isotopic separation of intermediate mass elements to be used in large double-beta decay experiments.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

d. High Performance Scintillators, Cherenkov Materials and Other Optical Components

Nuclear physics research has the need for high performance scintillator and Cherenkov materials for detecting photons and charged particles over a wide range of energies (from a few keV to up to many GeV). These include crystalline scintillators (such as BGO, BaF2, LaBr etc.) and liquid scintillators (both organic and cryogenic noble liquids) for measuring electromagnetic particles, plastic scintillators for measuring charged particles, and Cherenkov materials for particle identification. Many of these detectors require large area coverage and therefore cost effective methods for producing materials for practical devices. Grant applications are sought to develop:

- New high density scintillating crystals with high light output and fast decay times.
- Improved techniques for producing high purity cryogenic noble liquid scintillators (particularly argon and xenon).
- Ultra-high-purity organic liquid scintillators with various dopants.
- Large-area, high optical quality Cherenkov materials.
- Precision Cherenkov radiators for Detectors of Internally Reflected Cherenkov Light (DIRCs).
- Cherenkov materials with indices of refraction between gases and liquids (e.g., Aerogel).
- Scintillators and Cherenkov materials that can be used for n/gamma discrimination using timing and pulse shape information or other method. .
- High light output plastic scintillating and wavelength-shifting fibers.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

e. Specialized Targets for Nuclear Physics Research

Grant applications are sought to develop specialized targets, including:

1. Polarized (with nuclear spins aligned) high-density gas or solid targets capable of withstanding high electron or proton beam currents beyond the current state of the art; polarized 3He targets,

especially novel high-pressure circulating gas concepts matching the next generation of high-luminosity electron and photon beam experiments;
2. Very thin windows (<100 micrograms/cm^2 and/or 50% transmission of 500 eV X-rays) for gaseous detectors, for the measurement of low-energy ions; and
3. A positron-production target capable of converting hundreds of kilowatts of electron beam power (10 MeV at 10 mA) over a sufficiently short distance to allow for the escape of the produced positrons. Of particular interest would be moving and/or cooled high-Z targets of uniform, stable thickness (2-8 mm), which may be immersed in a 0.5-1.0 T axial magnetic field.

Grant applications also are sought to develop the technologies and sub-systems for the targets required at high-power, rare isotope beam facilities that use heavy ion drivers for rare isotope production. Targets for heavy ion fragmentation and in-flight separation are required that are made of low-Z materials and that can withstand very high power densities and are tolerant to radiation.

Finally, grant applications are sought to develop techniques for:
1. Production of thin films (in the thickness range from a few μg/cm^2 to over 10 mg/cm^2) for charge-state stripping in heavy-ion accelerators; and
2. Preparation of targets of radioisotopes, with half-lives in the range of hours, to be used off-line in both neutron-induced and charged-particle-induced experiments.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

f. Technology for High Radiation Environments

Next generation rare isotope beam facilities require new and improved techniques, instrumentations and strategies to deal with the anticipated high radiation environment in the production, stripping and transport of ion beams. These could also be useful for existing facilities. Therefore grant applications are sought to develop:

1. Rotary vacuum seals for applications in high-radiation environment: Vacuum rotary feedthroughs for high rotational speeds, which have a long lifetime under a high-radiation environment (order of months to years at 0.5-15 MGy/month), are highly desirable for the realization of rotating targets and beam dumps for rare isotope beam production and beam strippers in high-power heavy-ion accelerators.
2. Radiation resistant magnetic field probes based on new technologies: An issue in all high-power target facilities and accelerators is the limited lifetime of conventional nuclear magnetic resonance probes in high-radiation environments (0.1-10 MGy/y). The development of radiation-resistant magnetic field probes for 0.2-5 Tesla and a precision of $dB/B<10^{-4}$ is highly desired.
3. Improved models of radiation transport in beam production systems: The use of energetic and high-power heavy ion beams at future research facilities will create significant radiation fields. Radiation transport studies are needed to design and operate facilities efficiently and safely. Advances of radiation transport codes are desired for (a) the inclusion of charge state distributions of initial and produced ions including distribution changes when passing through material and magnetic fields, (b) efficient thick-shield, heat deposition, and gas production studies, (c) the implementation of new models of heavy ion radiation damage, and their validation against experimental data.
4. Radiation tolerant sensors for video cameras: Cost efficient video sensors with resolutions of VGA

(640 × 480 pixel) or better but with enhanced radiation tolerance for prolonged operation in the presence of neutron fluxes of about 10^5 n cm^{-2} s^{-1}, would be beneficial in the operation and remote handling of equipment in radiation fields, e.g. at rare isotope production facilities.

5. Fast neutron and photon dose-equivalent area monitors: Neutron and photon dose-equivalent area monitors that are fast and pulsed beam capable, have minimal total dead time, have dose response to high energy radiation (e.g. neutron energies > 1 GeV), and can meet high safety standard requirements (e.g. IEC 61511) would be beneficial at high power research accelerator facilities like FRIB or medical accelerator facilities where full beam loss accidents can have significant dose consequences. Response times in the range of 0.3 seconds or faster are desirable.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

g. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov.

References: Subtopic a:

1. Garutti, E., 2011, Silicon Photomultipliers for High Energy Detectors, *Journal of Instrumentation,* Vol. 6, Issue 10. (http://iopscience.iop.org/1748-0221/6/10/C10003)

2. For development of iron-free magnet systems with tilted crossed solenoid windings listed above interested parties should contact Dr. Daniel Bazin, NSCL/MSU (bazin@nscl.msu.edu).

References: Subtopic b:

1. M. Descovich, et al, 2005, In-beam measurement of the position resolution of a highly segmented coaxial Ge detector, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, Volume 553, Issue 3, pp. 535-542. (http://www.sciencedirect.com/science/article/pii/S0168900205014385)

2. For questions related to items above listed under general field of micropattern gas detectors contact Dr. Bernd Surrow (surrow@temple.edu)

3. For questions related to advancement of more conventional gas tracking detector systems contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu)

4. For item 2 listed above under development of detectors for rare isotope beam s contact Dr. Marc Hausmann, FRIB/MSU (Hausmann@frib.msu.edu).

References: Subtopic c:

1. Andersen, T. C. et al, Measurement of Radium Concentration in Water with Mn-coated Beads at the Sudbury Neutrino Observatory, *Nuclear Instruments and Methods in Physics Research A: Accelerators, Spectrometers, Detectors and Associated Equipment*, Vol. 501, pp. 399. 2003 (http://www.sciencedirect.com/science/article/pii/S0168900203006168)

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References: Subtopic e:

1. For questions related to technologies for high-power targets for FRIB contact Dr. Wolfgang Mittig, NSCL/MSU (mittig@nscl.msu.edu)

References: Subtopic f:

1. DOE Funding Opportunity Announcement (FOA), 2008, Fact Sheet: Facility for Rare Isotope Beams (FRIM Applicant Selection). (http://energy.gov/articles/fact-sheet-facility-rare-isotope-beams-frib-applicant-selection)

2. Burgess, T.W., et. al., 2011, Remote Handling and Maintenance in the Facility for Rare Isotope Beams, 13th Robotics & Remote Systems for Hazardous Environments • 11th Emergency Preparedness & Response, American Nuclear Society. p. 14. (http://www.researchgate.net/publication/255245516_Remote_Handling_and_Maintenance_in_the_Facility_for_Rare_Isotope_Beams)

3. MCNPX, 2013, Website. (http://mcnpx.lanl.gov/)

4. (PHITS) Particle and Heavy Ion Transport code System, Website. (http://phits.jaea.go.jp/)

5. Mokhov, N.V., and Striganov, S.I., 2007, MARS15 Overview, AIP Conference Proceedings 896, pp. 50-60. (http://dx.doi.org/10.1063/1.2720456)

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8. K. U. Vandergriff, Designing Equipment for Use in Gamma Radiation Environments, ORNL/TM-11175, Oak Ridge National Laboratory, May 1990 (http://dx.doi.org/10.2172/814580)

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10. York, R., et al., 2010, Status and Plans for the Facility For Rare Isotope Beams at Michigan State University, XXV Linear Accelerator Conference (LINAC10); Tsukuba, Japan; September 12-17. MOP046 (http://spms.kek.jp/pls/linac2010/TOC.htm).

11. For rotary vacuum seals listed above contact Dr. Frederique Pellemoine, FRIB/MSU (pellemoi@frib.msu.edu).
    For multiple-use vacuum seals listed above contact Tom Burgess, ORNL/NSED (burgesstw@ornl.gov).

12. For radiation resistant magnetic field probes listed above contact Dr. Georg Bollen, FRIB/MSU (bollen@frib.msu.edu).

13. For models of radiation transport in beam production systems and for fast neutron and photon dose-equivalent area monitors contact Dr. Reg Ronningen, NSCL/MSU (ronningen@frib.msu.edu).

14. Caresana, M., et al., 2014, Intercomparison of Radiation Protection Instrumentation in a Pulsed Neutron Field, Nuclear Instruments and Methods in Physics Research A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 737 pp. 203–213. (http://dx.doi.org/10.1016/j.nima.2013.11.073)

References:

1. NP SBIR/STTR Topic Associate(s) for Instrumentation, Detection Systems and Technique: Elizabeth Bartosz (Elizabeth.Bartosz@science.doe.gov)

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10. York, R., et al., 2010, *Status and Plans for the Facility For Rare Isotope Beams at Michigan State University*, XXV Linear Accelerator Conference (LINAC10); Tsukuba, Japan; September 12-17, MOP046. (http://spms.kek.jp/pls/linac2010/TOC.htm).

11. NP SBIR/STTR Topic Associate(s) for Electronics and Circuits: Elizabeth Bartosz: (Elizabeth.Bartosz@science.doe.gov)

12. sPHENIX, 2014, The sPHENIX Upgrade Proposal. (http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf)

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25. NUCLEAR PHYSICS ISOTOPE SCIENCE AND TECHNOLOGY

Maximum Phase I Award Amount: **$150,000**	*Maximum Phase II Award Amount:* **$1,000,000**
Accepting SBIR Phase I Applications: **YES**	*Accepting SBIR Fast-Track Applications:* **YES**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **YES**

Stable and radioactive isotopes are critical to serve the broad needs of modern society and to research in chemistry, physics, energy, environmental sciences, material sciences and for a variety of applications in industry and national security. A primary goal of the Department of Energy's Isotope Development and Production for Research and Applications Program (Isotope Program) within the Office of Nuclear Physics (NP) is to support research and development of methods and technologies which make available isotopes used for research and applications that fall within the Isotope Program portfolio. The Isotope Program produces isotopes that are in short supply in the U.S. and of which there exists insufficient domestic commercial production capability; some exceptions include some special nuclear materials and molybdenum-99, for which the National Nuclear Security Administration has responsibility. The benefit of a viable research and development program includes an increased portfolio of isotope products, more cost-effective and efficient production/processing technologies, a more reliable supply of isotopes year-round and the reduced dependence on foreign supplies. Additional guidance for research isotope priorities is provided in the Nuclear Science Advisory Committee Isotopes (NSACI) report published in 2008 and available at (http://science.energy.gov/np/nsac/). An updated version of this report will be published in 2015. The NSACI reports serve to guide production plans and research activities supported by the Isotope Program

All entities submitting proposals to SBIR/STTR Isotope Science and Technology topic must recognize the moral and legal obligation to comply with export controls and policies that relate to the transfer of knowledge that has relevance to the production of special nuclear materials (SNM). All parties are responsible for U.S. Export Control Laws and Regulations, which include but may not be limited to regulations within the Department of Commerce, Nuclear Regulatory Commission and the Department of Energy.

a. Novel or Improved Production Techniques for Radioisotopes or Stable Isotopes

Research should focus on the development of advanced, cost-effective and efficient technologies for producing isotopes that are in short supply and that are needed by research or applied communities. This includes advanced accelerator and beam transport technologies such as the application of high-gradient particle accelerating structures, high-energy/high-current cyclotrons, or other technologies that could lead to compact sources and target approaches needed to optimize isotope production. The development of high quality, robust accelerator targets is required to utilize high-current high-power-density available from advanced accelerators; of particular concern is the design and fabrication of encapsulated salt targets and liquid metal targets. These targets could be subjected to energies greater than 50 MeV at beam currents of 100 μA to 750 μA. The successful research grants should lead to breakthroughs that will facilitate an increased supply of isotopes that complement the existing portfolio of isotopes produced and distributed by the Isotope Program. This includes breakthroughs in in-situ target diagnostics, novel self-healing materials with extreme radiation resistance for accelerator target material containment or encapsulation. Improved thermal and mechanical modeling capabilities that include target material phase change and variable material density are also of interest to assist design of targets exhibiting high tolerance to extreme radiation and thermal environments.

The development of innovative technologies that will lead to new or advanced methods for production of radioisotopes needed by the scientific community, the medical community, industry, or for national purposes is encouraged. The 2009 NSAC-I report provides exemplary guidance; this report will be updated in 2015. In the medical community, production of radionuclides capable of functioning as diagnostic/therapeutic pairs or combining both traits are of particular interest (*e.g.*, ^{64}Cu/^{67}Cu or ^{44}Sc/^{47}Sc), as are novel or in-demand radionuclides with radioactive emissions of high linear energy transfer (LET), which are useful because of their potential for high toxicity to diseased cells while sparing nearby healthy tissue from damage. Proposed technologies must have real potential to ensure a cost-effective and stable supply and distribution of such isotopes. Development of technologies advancing production, handling and distribution/transportation of isotopes are encouraged. In addition, new approaches to hot-cell target fabrication technologies that will facilitate the recycling of precious target materials used in production of high purity radioisotopes are also sought. An area of significant interest is development of automation or robotics to handle and process large mass, highly radioactive thick targets typically used in high energy and photo-transmutation accelerator based production.

Grant applications are also sought for new technologies to produce large quantities of enriched isotopes. Enriched stable isotopes are used in radioisotope production targets and are important in fundamental nuclear physics experiments. Development of process technologies aimed at optimizing the recovery and recycling of enriched stable isotopes is of interest. Isotopes of interest for nuclear physics measurements include kg to ton quantities of germanium-76 (^{76}Ge), selenium-82 (^{82}Se), tellurium-130 (^{130}Te) and xenon-136 (^{136}Xe).

New production methods for mg quantities of transuranium elements such as californium-249 (^{249}Cf), californium-251 (^{251}Cf) and berkelium-249 (^{249}Bk), and ng quantities of einsteinium-254 (^{254}Es), and fermium-257 (^{257}Fm) of interest to the heavy element research community. These and other materials are needed for chemistry research, rare particle and rare decay experiments, and heavy element creation in nuclear physics research. Guidance for research isotope priorities is provided in the 2009 NSACI report. http://science.energy.gov/np/nsac/) as updated in the soon to be published 2015 NSACI long range plan. Novel methods are also sought for separation of stable isotopes that are needed in small quantities, as listed in the NSACI reports.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

b. Improved Radiochemical Separation Methods for Preparing High-Purity Radioisotopes

Separation from contaminants and bulk material and purification to customer specifications are critical processes in the production cycle of a radioisotope. Many production strategies and techniques used presently rely on old technologies and/or require a large, skilled workforce to operate specialized equipment, such as manipulators for remote handling in hot cell environments. Conventional separation methods may include liquid-liquid extraction, column chromatography, electrochemistry, distillation or precipitation and are used to separate radioactive and non-radioactive trace metals from target materials, lanthanides, alkaline and alkaline earth metals, halogens, or organic materials. High-purity isotope products are essential for high-yield protein radiolabeling for radiopharmaceutical use, or to replace materials with undesirable radioactive emissions. Improved product specifications and reduced production costs can be achieved through improvements in separation methods. Of particular interest are

developments that automate routine separation processes in order to reduce operator labor hours and worker radiation dose, including radiation hardened semi-automated modules for separations or radiation hardened automated systems for elution, radiolabeling, purification, and dispensing. Such automated assemblies should be easily adaptable to different processes and different hot cell configurations, and should consider ease of compliance with current good manufacturing practices (cGMP) for clinically relevant radionuclides.

Applications are sought for innovative developments and advances in separation technologies to reduce processing time, to minimize radiation exposure to personnel, to improve separations efficiencies, to automate separation systems, to minimize waste streams, and to develop advanced materials for high-purity radiochemical separations. In particular, the Department seeks breakthroughs in lanthanide and actinide separations. Incremental improvements are also encouraged, such as (1) in the development of higher binding capacity and selectivity of resins and adsorbents for radioisotope separations to decrease void volume and to increase activity concentrations, (2) the scale-up of separation methods demonstrated on a small scale to large-capacity production level, and (3) new resin and adsorbent materials with increased resistance to radiation..

In actinide radiochemistry, innovative methods are sought a) to improve radiochemical separations of or lower-cost approaches for producing high-purity alpha-emitting radionuclides such as radium-225, actinium-225 and actinium-227 from contaminant metals, including thorium, radium, lead, lanthanides, and/or bismuth; or b) to improve ion-exchange column materials needed for generating lead-212 from radium-224, and bismuth-213 from actinium-225 and/or radium-225. Advanced methods for the preparation of high purity radium-225 and actinium-225 from irradiated thorium targets are of particular interest. The new technologies must be applicable in extreme radiation fields that are characteristic of chemical processing involving high levels of alpha-and/or beta-/gamma-emitting radionuclides.

Recent advances in translation and clinical trials of alpha-particle mediated therapies have focused attention on the production and purification of long lived parent radionuclides for radium-223 and lead-212 production. Regulatory approval for the treatment of metastatic bone cancer originating from advanced prostate cancer using radium-223 dichloride has been obtained from the US Food and Drug Administration and initial phase I clinical trials of lead-212-TCMC-Trastuzumab for treatment of HER-2 expressing carcinoma (e.g., ovarian, pancreatic, peritoneal), are currently being conducted in the US. However sufficient amounts of the parent isotopes are not available to support full clinical implementation. Innovative methods are sought for 1) the production of actinium-227 and thorium-228, 2) the purification of actinium-227 and thorium-228 from contaminating target materials and decay chain daughters, and 3) the generation of high specific activity radium-223 and lead-212 for clinical applications. 4) the development and production of matched pair imaging isotopes for the alpha emitters to accurately determine patient specific dosimetry to improve treatment efficacy and safety. Proposals that consider novel production schemes for other alpha-emitting isotopes with potential therapeutic utility would also be of interest.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov. Also can contact the NP Topic Associate (TA) listed at the beginning of the References section for this topic.

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Manouchehr.farkhondeh@science.doe.gov

References: Subtopic a:

1. For further specifications contact Dr. Meiring Nortier of LANL (meiring@lanl.gov) or Dr. Brian Egle of ORNL (egleb@ornl.gov).

References: Subtopic b:

1. For further specifications contact Dr. Saed Mirzadeh (mirzadehs@ornl.gov) at ORNL, Dr. Leonard Mausner (lmausner@bnl.gov) at BNL. or Dr. Jonathan Engle at LANL (jwengle@lanl.gov)

References:

1. NP SBIR/STTR Topic Associate for Isotope Science and Technology: Dennis Phillips: (Dennis.Phillips@science.doe.gov).

2. NSAC Isotopes Subcommittee, 2009, Nuclear Science Advisory Committee Isotopes (NSACI) Final report; *Compelling Research Opportunities Using Isotopes,* one of the two 2008 NSAC Charges on the National Isotopes Production and Application Program. (http://science.energy.gov/~/media/np/nsac/pdf/docs/nsaci_final_report_charge1.pdf). It is anticipated that a new Long Range Plan related to the Isotope Program will be published in 2015 that will provide additional guidance on topics of interest.

3. Norenberg, J., Stapples, P., Atcher, R., et al., 2008, Report of the *Workshop on The Nation's Need for Isotopes: Present and Future*, Rockville, MD, August 5-7. DOE/SC-0107 (http://science.energy.gov/~/media/np/pdf/program/docs/workshop_report_final.pdf)

4. Qaim, S.M., 2012, The Present and Future of Medical Radionuclide Production. Radiochimica Acta, 100 (8-9), pp. 635-651. (ISSN: 0033-8230) (https://inis.iaea.org/search/search.aspx?orig_q=RN:44029002)