PROGRAM AREA OVERVIEW: OFFICE OF DEFENSE NUCLEAR NONPROLIFERATION

The Defense Nuclear Nonproliferation (DNN) mission is to provide policy and technical leadership to limit or prevent the spread of materials, technology, and expertise relating to weapons of mass destruction; advance the technologies to detect the proliferation of weapons of mass destruction worldwide; and eliminate or secure inventories of surplus materials and infrastructure usable for nuclear weapons. It is the organization within the Department of Energy's National Nuclear Security Administration (NNSA) responsible for preventing the spread of materials, technology, and expertise relating to weapons of mass destruction (WMD).

Within DNN, the Research and Development (R&D) program office sponsors long-term development of new and novel technology that reduces the threat to national security posed by nuclear weapons proliferation and detonation or the illicit trafficking of nuclear materials. Using the unique facilities and scientific skills of NNSA and DOE national laboratories and plants, in partnership with industry and academia, the program conducts research and development that supports nonproliferation mission requirements necessary to close technology gaps identified through close interaction with NNSA and other U.S. government agencies and programs. This program meets unique challenges and plays an important role in the federal government by driving basic science discoveries and developing new technologies applicable to nonproliferation, homeland security, and national security needs. DNN R&D has two sub-Offices: Proliferation Detection and Nuclear Detonation Detection.

The Office of Proliferation Detection (PD) advances basic and applied technologies for the larger nonproliferation community. Proliferation Detection develops the tools, technologies, techniques, and expertise for the identification, location, and analysis of the facilities, materials, and processes of undeclared and proliferant nuclear weapons programs and to prevent the diversion of special nuclear materials, including use by terrorists.

The Nuclear Detonation Detection Office (NDD) builds the nation's operational sensors that monitor the entire planet from space to detect and report surface, atmospheric, or space nuclear detonations; and produces and updates the regional geophysical datasets enabling operation of the nation's ground-based seismic monitoring networks to detect and report underground detonations. NDD conducts research and development on nuclear detonation forensics, improvements in satellite operational systems to meet future requirements and size and weight constraints, and in radionuclide sampling techniques for detection of worldwide nuclear detonations.

1. ALTERNATIVE RADIOLOGICAL SOURCE TECHNOLOGIES

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

This objective focuses on the R&D needed to replace high activity radioactive sources that are deemed to pose a significant risk if malevolently used. Our current emphasis is on emerging and innovative technologies and techniques for the replacement of these sources with non-radioisotope based technologies. Radioactive sources serve a number of critical functions including the treatment and diagnosis of disease, the inspection and certification of critical mechanical structures, the sterilization of food and medical products, and the exploration for petroleum. Replacements or alternatives proposed

must provide equivalent (or improved) functionality and be less susceptible to malevolent use. Each proposal must address: economic feasibility of the proposed alternative or replacement, ease of maintenance (both the equipment and the source) and relative accessibility in and around the device.

DNN R&D holds an annual University Information Technical Interchange (UITI) program review meeting where University and SBIR projects are presented to the program managers. All awardees are required to attend and present their progress this annual meeting.

Grant applications are sought only in the following subtopics:

a. Alternative Formation Density Well Logging Tool

Radioactive sources are commonly used in the well logging industry. The most accurate measurement of downhole rock density requires as much as 2.5Ci of 137Cs. The DNN R&D program office is seeking ways to improve nuclear magnetic resonance (NMR) and acoustic methods already in use. The development of new NMR and acoustic sensors for well logging is of particular interest. These methods require significant signal processing, de-convolution or inversion for optimal data interpretation. The DNN R&D program office is seeking new ideas for NMR and acoustic data signal processing. All proposals for novel sensor or data signal processing techniques to this topic should focus on the development of short term development of well logging tools.

Questions – Contact: Arden Dougan, Arden.Dougan@nnsa.doe.gov

b. Other

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

Questions – Contact: Arden Dougan, Arden.Dougan@nnsa.doe.gov

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1. National Research Council, Committee on Radiation Source Use and Replacement, 2008, Radiation Source Use and Replacement: Abbreviated Version, The National Academies Press, Washington, DC, ISBN: 978-0-309-11014-3. http://www.nap.edu/openbook.php?record_id=11976

2. Badruzzaman, et al., August 4-5, 2009, Radioactive Sources in Petroleum Industry: Applications, Concerns and Alternatives. SPE Asia Pacific Health, Safety, Security, and Environment Conference and Exhibition, SPE 123593, ISBN: 978-1-55563-260-1, available at https://www.onepetro.org/conference-paper/SPE-123593-MS

3. Freedman, R., 2006, Advances in NMR Logging, Society of Petroleum Engineers, SPE paper, no. 89177. https://lagunita.stanford.edu/c4x/HumanitiesSciences/CHEM291/asset/Freedman_2006.pdf

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5. Saito, N. and Coifman, R., 1997, Extraction of Geological Information from Acoustic Well-logging Waveforms Using Time-frequency Wavelets, Geophysics, vol. 62, no. 6, pp. 1921–1930. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.42.6425&rep=rep1&type=pdf

2. INTERNATIONAL SAFEGUARDS

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

This program supports NNSA's nuclear nonproliferation mission by developing innovative safeguards technologies to enhance verification of nuclear materials and activities. The Office of Defense Nuclear Nonproliferation Research and Development (NA-22) includes R&D in nuclear (and relevant nonnuclear) measurements, field instrumentation and containment & surveillance. The program develops technologies to detect diversion of nuclear material from declared facilities, to detect undeclared nuclear material and activities from declared facilities, and to verify compliance with arms control treaties and agreements related to the control of nuclear material, its production or processing.

Defense Nuclear Nonproliferation Research and Development holds an annual University Information Technical Interchange (UITI) program review meeting where University and SBIR projects are presented to the program managers. All awardees are required to attend and present their progress at this annual meeting.

Grant applications are sought only in the following subtopics:

a. Instruments for Nondestructive Fast Neutron Analysis in the Context of International Safeguards.

DNN R&D has a need for robust instruments to provide nondestructive fast neutron analysis of safeguard relevant materials. These materials will have high gamma-ray emission, so the measurement system must be capable of efficient gamma-ray rejection. Such instruments are needed to detect partial defect analysis (missing pins) on spent fuel assemblies and materials accounting using neutron coincidence analysis of fissile materials.

Questions – Contact: Arden Dougan, Arden.Dougan@nnsa.doe.gov

b. Instruments for Gamma Ray Imaging in the Context of International Safeguards.

DNN R&D has a need for robust instruments to provide gamma ray images of safeguards relevant materials and facilities. The imagers may be used to assist safeguards inspectors in confirming the presence or absence of nuclear material in complementary access, enrichment plants, fresh fuel, hold-up monitoring, managed access, surveillance or waste monitoring. These instruments will be challenged with low signal to noise, and significant standoff. The instruments can be based on any combination of technologies such as Compton effect, pinhole coded aperture, LIDAR, Cadmium-Zinc-Telluride (CZT) sensors, etc.

Questions – Contact: Arden Dougan, Arden.Dougan@nnsa.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: Arden Dougan, Arden.Dougan@nnsa.doe.gov

REFERENCES:

Subtopic a

1. IAEA, 2013, International Atomic Energy Agency Department of Safeguards Long-Term R&D Plan, 2012-2023, milestones 5.7 and 5.8. https://www.iaea.org/safeguards/symposium/2014/images/pdfs/STR_375_--_IAEA_Department_of_Safeguards_Long-Term_R%26D_Plan_2012-2023.pdf

2. Reilly, D., Ensslin, N., Smith, H., and Krohner, S., 1991, Passive Nondestructive Assay of Nuclear Materials, USNRC, http://www.lanl.gov/orgs/n/n1/FMTTD/neut_mc/pdfs/LA_UR_90_0732.pdf

3. Knoll, G.E., 2000, Radiation Detection and Measurement, John Wiley & Sons. http://cds.cern.ch/record/441925/files/0471073385_TOC.pdf

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1. IAEA, 2013, International Atomic Energy Agency Department of Safeguards Long-Term R&D Plan, 2012-2023,milestone 5.1. https://www.iaea.org/safeguards/symposium/2014/images/pdfs/STR_375_--_IAEA_Department_of_Safeguards_Long-Term_R%26D_Plan_2012-2023.pdf

2. Phillips, G., 1995, Gamma-ray Imaging with Compton Cameras, Nuclear Instruments and Methods in Physics Research, B 99, pp. 674-677. http://www.sciencedirect.com/science/article/pii/0168583X95800859

3. RADIATION DETECTION

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

The Office of Nuclear Nonproliferation Research and Development (NA-22) is focused on enabling the development of next generation technical capabilities for radiation detection of nuclear proliferation activities. As such, the office is interested in the development of radiation detection techniques and sensors, and advanced detection materials, which address the detection and isotope identification of unshielded and shielded special nuclear materials, and other radioactive materials in all environments. In responding to these challenging requirements, recent research and development has resulted in the emergence of radiation detection materials that have good energy resolution. From these materials, the development of radiation detectors that are rugged, reliable, low power, and capable of high-confidence radioisotope identification are sought. Currently, the program is especially interested on the development of improved capabilities for scintillator detectors.

a. Scintillators for Gamma-ray Spectroscopy

Of interest is research on materials that will lead to practical high-brightness scintillators with energy resolution significantly better than the currently available sodium iodide-based gamma spectrometers and a t a cost lower than lanthanum bromide. Several new and promising formulations (including co-doping of known materials) have been discovered and synthesized in small quantities, but there is a need for industrial crystal-growth facilities to find ways to produce practical sizes of high-quality scintillators at a reasonable cost. As an alternative to crystal growth, techniques that produce high quality, large volume scintillators with good spectroscopic performance from the consolidation of powders are highly desirable. Moreover, a scintillator thick enough to absorb high energy gamma rays must also be very transparent to its own emitted light. A laboratory demonstration is expected in Phase I, while Phase II should lead to the development of a commercial process with a significant advantage over current crystal growth techniques.

Questions – Contact: David Beach, david.beach@nnsa.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: David Beach, david.beach@nnsa.doe.gov

REFERENCES:

Subtopic a:

1. Glenn F. Knoll, 2009, Radiation Detection and Measurement, Fourth Edition, John Wiley and Sons, New York, NY, http://www.amazon.com/Radiation-Detection-Measurement-Glenn-Knoll/dp/0470131489

2. Special Nuclear Materials Movement Detection Program Radiation Sensors and Sources Roadmap, October 2009. (Please email David Beach, david.beach@nnsa.doe.gov to request an electronic copy of this Roadmap.)

3. Advanced Materials for Radiation Detection – Roadmap, August 2010. (Please email David Beach, david.beach@nnsa.doe.gov to request an electronic copy of this Roadmap.)

Subtopic b:

1. Guss, P, et al., 2014, Results for Aliovalent Doping of CeBr3 with Ca2+, Journal of Applied Physics, vol. 3, p. 115, 034908, http://scitation.aip.org/content/aip/journal/jap/115/3/10.1063/1.4861647

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4. TECHNOLOGY TO FACILITATE MONITORING FOR NUCLEAR EXPLOSIONS

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

Ground-based Nuclear Detonation Detection Research and Development (GNDD R&D) is sponsored by the U.S. Department of Energy's National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation Research and Development. GNDD is responsible for the research and development necessary to provide the U.S. Government with capabilities for monitoring nuclear explosions. The goal of the GNDD program is to advance the U.S. ground-based nuclear explosion monitoring capabilities to detect, locate, identify and determine yield of events associated with foreign nuclear weapons development [Reference 1]. Proposals that enhance U.S. capabilities that also benefit the international monitoring capabilities in the context of preparations for a Comprehensive Nuclear-Test-Ban Treaty (CTBT) may be submitted.

Research is sought to move toward commercialization of algorithms, hardware, and software that advance the state-of-the-art for event detection, location, and identification. Superior technologies will help improve the National Data Center's [Reference 2] ability to monitor for nuclear explosions, which are banned by several treaties and moratoria. Grant applications responding to this topic must:

(1) State the current state-of-the-art, in terms of relevant specifications such as sensitivity, reliability, maintainability, etc., as well as the performance goal of the proposed advance in terms of those same specifications; and

(2) Address the commercialization path of any instruments or components developed. Due to the small market potential of treaty monitoring technologies, this call is focused toward already existing or emerging commercial products for other applications that could be modified/enhanced for treaty monitoring applications. The resulting "treaty monitoring edition" of the product(s) would hopefully provide a performance advantage that would also benefit the original market and thereby leverage existing markets.

Aerosol nuclear debris are created by the fission of actinides during a nuclear explosion. These radioactive atoms, if they are allowed to enter the atmosphere, can travel around the globe, and their ratios can prove unequivocally that the source was an explosion. Samples are collected for monitoring treaties and moratoria from ground-based and flight-based systems, and this solicitation will address improving the technology for both below, as sections (a) and (b).

Many ground-based particulate detection systems of today were developed or modified for the CTBT International Monitoring System (IMS). [Reference 3] The Radionuclide Aerosol Sampler/Analyzer (RASA) is one such system that was developed for and is currently deployed in the CTBT IMS [Reference 4-8]. Deployed RASA's were a key tool in reporting the aerosol radioactivity release from the Fukushima nuclear reactor accident [Reference 9]. A number of lessons have been learned from these deployments that should be incorporated in the design of a next generation aerosol system.

Flight collection encompasses different challenges. The key difference is that air flow is provided by aircraft motion and requires that a sampler handle high pressure differential across the filter or very high (2.0 m3/s) flow velocity.

a. Ground-Based Radionuclide Aerosol Collection Technology Improvements and Commercialization

Background

One key lesson learned from the Fukushima accident was that the high power demand of the RASA lessened system stability and reliability (uptime) when it was most critically needed. The current version of the RASA requires a 3 hp blower to pull air through the filter at a high rate (~1000 m3/hr) with a variable velocity control to keep that rate steady as aerosols build up on the filter. When power near Takesaki, Japan was intermittent due to the East Tohoku earthquake, an uninterruptible power supply (UPS) maintained operation to critical components of the RASA: the control computer and detector. However, blower power demands were too high for a practical UPS causing aerosol sampling to stop. A solution is to substitute electrostatic precipitation for classical filtration, as the blower power requirement for sampling would drop by a large factor.

RASA sensitivity could be improved. When natural radioactivity is high, RASA equipment sensitivity can just barely meet the minimum CTBT certification standard. This provides a reliability issue in the face of a simultaneous degradation in another RASA component. Electrostatic precipitation would address this issue as well, by allowing a modest (perhaps 2x) increase in collected air volume to move the RASA sensitivity safely away from the minimum requirement.

The RASA is an integrated system that has an aerosol collector of 0.2 m2 area, a scheme for decaying filters, and a special-geometry radiation detector. RASA automatically transports the filters through subsystems which provide collection, sealing, and finally measurement, as described in references 4 and 5. The goal of this work would be new technology that could conceptually (not necessarily literally) replace the collection subsystem in RASA. Further, the technology sought might require replication. That is, it might be that the product of this development is a demonstration system of 0.1 m2 area, of which two would be required to achieve the collection capability of the current RASA single collector subsystem.

Sharma et al. have demonstrated a practical electrostatic system [Reference 10] that shows promise for electrostatic precipitation replacing filtration in the RASA, at high efficiency and undiminished by ~10,000 m3 of collection. Key is the removal of the collected debris for analysis. New concepts for using a moving substrate in an automated electrodeposition system have been developed. The intent is for the electrostatic precipitator to replace the filtration component of the RASA with only minor retrofit.

Proposals are sought for a collection component of a next generation ground-based aerosol system, which could replace the traditional moving filter design of the RASA collector and that meet requirements in Table 1 below. Stretch goals are identified in some areas, but conformance to those parameters is not required. Themes in improvements include the following:

- Sample-change mechanisms for transferring particulate debris from the electrostatic deposition plates to the radiological detectors of the RASA
- Eliminating or minimizing the potential for sample-to-sample cross contamination in the sampler and sample-change mechanism
- Reduced power for collection
- Increased system sample volume, possibly by use of two or more collectors

- Improved sample geometry (smaller sample package) for measurement
- High collection efficiency, which is not substantially reduced by collecting >20,000 m3 of surface air

This call for proposals does not deal with the precipitator's integration into the RASA – that would occur in a later phase. At which time care would need to be taken to consider the second order effects of proposed solutions on overall system performance.

Table 1: Ground Based ESP Collection Requirements

Requirement	Value(s)
Component Efficiency vs Particle Size	0.1 - 1 micron (≥90% efficiency); ≥10 microns (≥50% efficiency)
Component Sample Volume per Hour	≥500 m3
Sample Dimensions	area (10x10cm); thickness (<5mm)
Sample Mass Range without loss of efficiency	0.01 @ 10 micro g/m3 (low loading); 0.06 @ 60 micro g/m3 (high loading); 2 @ 2 milli g/m3 (ultra-high loading as a stretch goal).
Face Velocity in Component	1.4 m/s (~1000 m3/hr in existing RASA with 0.2 m2 collection area); 13-50 m/s (500 m3/hr to 2000 m3/hr; 200 m/s (stretch goal).
Operating Air Temperature	-20° C to 50° C (-4° F to 120° F)
Moisture Content	20 – 100% relative humidity
Corrosiveness	pH = 5.6
Sample change time	< 5 min
Overall component dimension envelope	RASA envelope is 42 x 23 x 5 inches (may accommodate multiple electrostatic precipitators)

Questions – Contact: Leslie Casey, leslie.casey@nnsa.doe.gov

b. Flight-Based Radionuclide Aerosol Collection Technology Improvements and Commercialization

Background

Samples required for airborne collection are similar to ground based needs, with the exception of the means of delivery of the particulate matter onto the filter media. Airborne samples are collected on the filter not by drawing air through the filter, but rather by pushing the sample onto the filter by the movement of the aircraft through the air stream. Filter material can be injected into the air stream as part of a roll of filter paper or as individual filters. The filters are removed after the flight and sent for analysis. Typical airborne sampling times are 30-60 minutes, leading to total volumes sampled at 2000-5000 m3 on a surface area of 0.2 m2. Air flow is the main difference between airborne and ground collection. Air flights of several hours will collect several samples. Maximum velocity for a typical jet aircraft during sampling may be around 480 km/h, which is about 300 mph or 135 m/s. It is also described as 0.40 Mach. Ground based samplers collect at speeds of 0.1 to 1.0 m/s. Air samples may be taken by aircraft flow at slower speeds, but they will all tend to be several magnitudes higher that a ground based system. Electrostatic precipitation depends on charging the

aerosol particles, then accelerating them across a gap filled with turbulent air. If the gas velocity greatly reduces the residence time of the particle between the plates, collection efficiency will suffer greatly.

Proposals are sought for a collection component of a flight aerosol system which could replace the traditional filtration approach with electrostatic precipitation and which meet requirements in Table 2 below. Themes in improvements include the following:

- Sample-change mechanisms for transferring particulate debris from the electrostatic deposition plates to a point of collection for storage on the aircraft
- Eliminating or minimizing the potential for sample-to-sample cross contamination in the sampler and sample-change mechanism
- Compact design within the surface area of 0.25 m2 and a volume of not to exceed 0.25 m3

This call for proposals does not deal with the precipitator's integration into a flight system – that would occur in a later phase at which time care would need to be taken to consider the second order effects of proposed solutions on overall system performance.

Table 2: Flight Based ESP Collection Requirements

Requirement	Value(s)
Component Efficiency vs Particle Size	0.1- 1 micron (≥90% efficiency); ≥10 microns (≥50% efficiency)
Component Sample Volume per Half Hour	≥2000 m3
Sample Dimensions (not including sample changer and sample collection)	area (<40x50cm); thickness (<10cm)
Sample Mass Range without loss of efficiency	0.001 g @ 1 micro g/m3 (low loading); 0.005 g @ 5 micro g/m3 (high loading).
Face Velocity in Component	135 m/s (assumes a 40 cm x 50cm component face area).
Operating Air Temperature	-20^{o} C to 50^{o} C (-4^{o} F to 120^{o} F)
Moisture Content	20 – 100% relative humidity
Corrosiveness	pH = 5.6
Sample change time	< 5 min
Overall component dimension envelope	60 cm x 72 cm x 55 cm

Questions – Contact: Leslie Casey, leslie.casey@nnsa.doe.gov

c. Advanced or Unique Active Seismic or Infrasound Sources

Active sources of seismic and infrasound energy can be used in a number of ways to improve Ground-based Nuclear Detonation Detection. Active sources can act as analogues for explosion events, aid in the characterization of Earth and atmospheric parameters, and serve as calibration for sensors. Proposals are sought for advanced or unique seismic or infrasound sources. Advanced or unique sources will be state-of-the-art in one or more of the following areas:

- Frequency content
- Strength
- Radiation pattern

- Type of energy generated (e.g. P or S waves)
- Time-domain signature
- Repetition rate
- Repeatability
- Mode of operation
- Cost effectiveness
- Portability
- Location of use (aerial, surface, borehole, underwater, etc.)
- Environmental impact

Questions – Contact: Dr. David LaGraffe, david.lagraffe@nnsa.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: Leslie Casey, leslie.casey@nnsa.doe.gov

REFERENCES:

1. Casey, L., January 2014, Goals, Objectives and Requirements of the Ground-based Nuclear Detonation Detection (GNDD) Team, Document No. DOE/NNSA/NA-22/GNDD-GOR-2014, doi: 10.2172/1130078, http://www.osti.gov/scitech/biblio/1130078/

2. Radionuclide Reports, International Monitoring System Data, U.S. National Data Center, http://www.usandc.gov/radionuclide.html.

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11. Ben-Menahem, A. and Jit Singh, S., 2012, Representations of Seismic Sources, Seismic Waves and Sources, Chapter 4, Springer Science & Business Media, http://link.springer.com/chapter/10.1007%2F978-1-4612-5856-8_4

5. IN-SITU SAMPLE PREPARATION

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

One of the principal challenges in high precision isotopic analysis using mass spectrometry is identifying and eliminating interfering species. For example, in small samples analyzed by Secondary Ion Mass Spectrometry (SIMS), 238U may complex with hydrogen to form 238UH, which appears at mass 239 and causes an interference with 239Pu. Although SIMS instruments may be designed with internal heating lamps that could partially address this challenge in some cases, the chamber itself may become a source of interferences if desorbed species are deposited on the walls of the analysis chamber and subsequently re-heated.

a. Methods to Reduce or Eliminate Interferences for In-Situ Analytical Instruments

A routine method by which to remove or overcome different types of interferences from is desired. Proposals should identify the types of interfering species to be removed, and the targeted sample size. For example, removal of adsorbed hydrogen and other volatiles from micron-sized particulate samples would be relevant to this call. The proposal should clearly describe the methods or approaches to be developed, how broadly applicable they would be to real-world samples and whether the method applies to interferences that are intrinsic to the sample itself, or those that could be introduced by sample preparation (e.g., epoxy), or both.1

Questions – Contact: Dr. Eleanor Dixon, eleanor.dixon@nnsa.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: Dr. Eleanor Dixon, eleanor.dixon@nnsa.doe.gov

REFERENCES

1. Keck, W.M., Cosmochemistry Laboratory: Sample Preparation http://www.higp.hawaii.edu/cosmochemistry/sampprep.html

6. ADVANCED SAMPLE REGISTRATION AND MANIPULATION FOR MICROSCOPIC ANALYSIS

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

Advances in modern microanalytical techniques have resulted in unprecedented capability to spatially resolve chemical, physical, and materials properties at length scales that span the nanometer to micrometer scales. Full materials characterization often requires combining several imaging microscopies (e.g., optical microscopy, scanning electron microscopy (SEM), secondary ion mass spectrometry (SIMS), and various spectroscopies) in a serial fashion in order to provide a complete analysis of a sample. One complication in imaging samples is that for repeated examinations of a particular (x, y, z) position, relocating it accurately (e.g., within microns) and rapidly (e.g., within minutes after the sample is removed from the microscope) can be challenging. Another complication is that samples can consist of solid particles and/or small aliquots of liquids that require delicate handling while maintaining sample integrity and avoiding contamination.

Therefore, of interest are innovations to acquire and relocate a particular place of interest within a large field of sample material, in ways to expedite making repeated analyses of the same specific location and to enable the application of more than one microscopic technique to image that same location. Such advances in sample manipulation and spatial referencing should be designed to manipulate microliter volumes of liquids, microgram quantities of solids, and/or particulate materials that are less than 100 microns in diameter. These materials need to be fixed to sample holding substrates made of various materials (e.g., glass, plastic, gold, aluminum, or steel), which may contain registration marks and navigational reference points that can be addressed during analysis. Thermal stability, electrical conductivity, material compatibility, and stability all must be maintained, such that regions of interest can be archived and reanalyzed as needed. Ideally, the sample handling, registration, and manipulation techniques would work across multiple analytical imaging and spectroscopic platforms with spatial reproducibility of at least 1 micron. The ultimate goal would be to reproducibly perform rapid analysis on the same location within a sample with multiple imaging techniques. For example, as a variation of laser peening, how well can a focused laser beam (or other source of energy) be directed near a place of interest in order to induce localized damage within the sample as an in-situ fiducial marker?

Grant applications are sought only in the following subtopics:

a. Optical Microscopy

Approaches to sample manipulation, and location that can be used during optical inspection of heterogeneous samples, and that potentially can be used on other microscopies. Sample substrates typically include glass or silicon and require registration at or better than the micron scale.

Questions – Contact: Tom Kiess, thomas.kiess@nnsa.doe.gov

b. Electron Microscopy

Approaches to sample preparation, manipulation, and location that can be used for electron microscopy (e.g., SEM) inspection of heterogeneous samples, and that potentially can be used on other microscopies. Sample substrates typically require conductive materials such as metal coated glass, silicon, or carbon and require registration at or better than the 100 nanometer scale.

Questions – Contact: Tom Kiess, thomas.kiess@nnsa.doe.gov

c. Micro/Nano Analytical Spectroscopy

Approaches to sample preparation, manipulation, and location that can be used during spatially resolved spectroscopic analysis (e.g., Raman, fluorescence, photoelectron, and x-ray spectroscopies) of heterogeneous samples, and that potentially can be used on other microscopies. Sample substrates typically include metal (Al or steel), glass, or silicon with the requirement that they do not interfere with spectroscopic analysis and require registration at or better than the micron scale.

Questions – Contact: Tom Kiess, thomas.kiess@nnsa.doe.gov

d. Spectrometry

Approaches to sample preparation, manipulation, and location that can be used during spatially resolved spectrometry (e.g., Secondary Ion Mass Spectrometry) of heterogeneous samples, and that potentially can be used on other microscopies. Sample substrates typically include aluminum or silicon and require registration at the submicron scale.

Questions – Contact: Tom Kiess, thomas.kiess@nnsa.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: Tom Kiess, thomas.kiess@nnsa.doe.gov

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7. REMOTE SENSING

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

One of the enduring programs within the Office of Defense Nuclear Nonproliferation Research and Development is to develop remote sensing technology that supports detection and characterization of signatures or activities related to nuclear proliferation
The Remote Sensing Program has been a cornerstone in the national capability for the detection of facilities and activities related to the proliferation of foreign nuclear programs. Remote Sensing research encompass a wide variety of capabilities to detect signatures associated with the development of nuclear weapons. The research areas in the Remote Sensing program include sensor development, image processing, and digital signal processing techniques for analysis and characterization of observed phenomena.

Grant applications are sought only in the following subtopics:

a. High-Time-Resolution Photon-Counting Imagers

High-speed (sub-ns) photon-counting imagers with high-spatial resolution (mega-pixel class) have many applications of interest to the DOE non-proliferation program, as well as to other national security problems. These applications include 3-dimensional imaging, low-light imaging, and flexible motion correction, as well as applications in neutron, ion and other particle detection. However, performance in this class of sensors, with no read noise and detailed time and position information about each individual photon, is directly dependent on maximum count rate for most of these applications. Therefore, research and development that enables improvements in size, weight, power and/or performance for megapixel-class sensor systems with count rates of ~100 million detected photons per second and sub-ns time resolution, like crossed strip sensor systems currently under development (refs 1,2), or that leads to sensor systems with even higher count rates (1 billion detected photons per second or higher) are sought. For the former class of sensors, electronics needs include high-channel density (>100 channels) low-noise (<1000 electron RMS) preamplifiers and low-power, high-channel density, high-speed (~GS/s) ADC's. For the latter, novel architectures are sought that enable mega-pixel class imagers that maintain high resolution spatial and temporal information on each photon detection while increasing overall count rate limits.

Questions – Contact: Victoria Franques, Victoria.franques@nnsa.doe.gov

b. Alternative Methods for Materials Measurements

In order to measure the optical constants of the complex index of refraction (n and k), one of the most common methods requires making near-specular reflectance measurements from the first

surface of the materials of interest. For certain materials (SiO2, BaF2, CaF2, KBr, Ge etc.) this is relatively easy and the experiments and measurements to determine n and k for such is common place. However, the greatest challenge in obtaining such data is not the measurement, but rather obtaining and preparing the materials with first surfaces that are conducive to specular reflectance, i.e. planar, polished, free of defects, and can be obtained in a reproducible fashion.
Growing single crystals is possible in some cases, but usually very time consuming. What is sought is a method to reproducibly and reliably grow such species with specular surfaces in a reliable fashion. Certain types of deposition can be envisioned (CVD, LVD, etc.) but significant improvements are sought to make the process quicker and more reliable at producing the reflective surfaces. Alternative methods are also sought. Materials that could be used to test such improved or alternate methods must include both organic and inorganic species such as BaF2, Na2SO4, Er2O3, Nd2O3, (NH4)2SO4, Nd(NO3)3-6H2O, Lactose, sucrose, etc

Questions – Contact: Victoria Franques, Victoria.franques@nnsa.doe.gov

c. Electronically Tunable, Narrow Bandpass Sensor for Imaging Proliferation Threats in the SWIR

In Proliferation Detection, there is a need to detect signatures of chemicals and materials in the spectral region 2.3 – 2.5 micrometers at high spectral resolution. We desire new passive remote-sensing devices capable of imaging ground scenes in daylight with a spectral resolution of approximately 0.1 to 2 nanometers. The high resolution is required to distinguish sharp features in the spectra of target materials. The device should provide an image so that target materials can be located in a cluttered scene. The device should be wavelength-tunable in order to discriminate the target from background materials and atmospheric interference; tuning ranges of 5-20 nanometers will probably be sufficient. As an example, tunable Fabry-Perot Image sensors have been developed for the long-wavelength infrared (7.9 to 11.2 micrometers) spectral region (Ref. 1), but these sensors were not designed for use in the desired spectral region of 2.3 – 2.5 micrometers. Another sensor operated in the 2.6 to 2.9 micrometer region, but with insufficient spectral resolution of 10 nm (Ref. 2). In astronomy, imaging sensors with a similarly high ratio of wavelength / bandwidth have been implemented, mostly in the visible spectral region (0.4 to 0.9 micrometers), but also cannot easily be extended to the infrared. Other concepts involving liquid-crystal tunable filters and coated optical filters may be effective. Image acquisition times should be in the range of 0.01 to 5 seconds and adjustable to reach radiance signal-to-noise ratios of ~800 depending on the observation conditions. There is a tradeoff between spectral resolution and spatial field of view; a wide angular field-of-view for the instrument of ~10 degrees is desirable, with pixel elements having angular FOVs less than 0.1 degrees. The sensor should be stable in ordinary environmental conditions encountered in typical outdoor field tests

Questions – Contact: Victoria Franques, Victoria.franques@nnsa.doe.gov

d. Remote Detection of Extremely Small Vibrations

Conventional vibration detectors have typical sensitivities of 1 micro-g per root Hertz (where g is the acceleration due to Earth's gravity). Recent developments have shown that new types of detectors, such as those based on the use of the fast-light effect induced by anomalous dispersion, can enhance the sensitivity to vibration by nearly six orders of magnitude. Devices based on these technologies may be configured for ultrasensitive sensing of many effects, including rotation and

vibration. Therefore, proposals are sought for the development of technology for remote detection of extremely small vibration signatures, with a sensitivity of at least 1 pico-g per root Hertz, representing a six orders of magnitude enhancement over the typical capability of current technologies. A proposed vibrometer must be able to detect vibrations in three orthogonal directions. The technology should be extremely compact, have a high dynamic range, be robust against environmental disturbances, and require low power. Phase I is to develop the feasibility, and Phase II is to build a prototype sensor.

Questions – Contact: Victoria Franques, Victoria.franques@nnsa.doe.gov

e. Other

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

Questions – Contact: Victoria Franques, Victoria.franques@nnsa.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY DELIVERY AND ENERGY RELIABILITY

The Office of Electricity Delivery and Energy Reliability (OE) provides national leadership to ensure that the Nation's energy delivery system is secure, resilient, and reliable. OE works to develop new technologies to enhance the infrastructure that brings electricity into our homes, offices, and factories and to improve the federal and state electricity policies and programs that shape electricity system planning and market operations. OE also works to bolster the resiliency of the electric grid and assists with restoration when major energy supply interruptions occur.

OE recognizes that our Nation's sustained economic prosperity, quality of life, and global competitiveness depend on access to an abundance of secure, reliable, and affordable energy resources. The mission of OE is to drive electric grid modernization and resiliency in the energy infrastructure. Through a mix of technology and policy solutions, OE will address the changing dynamics and uncertainties in which the electric system will operate. OE leverages effective partnerships, solid research, and best practices to address diverse interests in achieving economic, societal, and environmental objectives.

OE has a broad portfolio of activities that spans technology innovation, institutional support and alignment, and security and resilience. Serving as the lead for the Department of Energy's efforts on grid modernization, OE works closely with diverse stakeholders to ensure that clean energy technologies can be integrated in a safe, reliable, and cost-effective manner.

For additional information regarding OE's activities and priorities, click here.

Further information regarding the challenges and needs associated with the Nation's energy infrastructure can be found in the 2015 releases of the Department's Quadrennial Energy Review and Quadrennial Technology Review.

8. ADVANCED GRID TECHNOLOGIES

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

The electric power system is facing increasing stress due to fundamental changes in both supply and demand technologies. On the supply side, there is a shift from large synchronous generators to lighter-weight generators (e.g., gas-fired turbines) and variable resources (renewables). On the demand side, there is a growing number of distributed and variable generation resources, as well as a shift from large induction motors to rapidly increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The communications and control systems are also transitioning from analog systems to systems with increasing digital control and communications; from systems with a handful of control points at central stations to ones with potentially millions of control points.
Grid modernization will require the adoption of advanced technologies, such as smart meters, automated feeder switches, fiber optic and wireless networks, energy storage, and other new hardware. It must also encompass the application of intelligent devices, next-generation components,

cybersecurity protections, advanced grid modeling and applications, distributed generation, and innovative architectures. These technologies require a new communication and control layer to manage a changing mix of supply- and demand-side resources and to provide new services.

The transition to a modern grid will create new technical challenges for an electric power system that was not designed for today's requirements. Customers have never relied more on electricity, nor been so involved in where and how it is generated, stored, and used. Utilities will continue retrofitting the existing infrastructure with a variety of smart digital devices and communication technologies needed to enable the highly distributed, two-way flow of information and energy. Reliability, resilience, and security will remain a top priority as aging infrastructure and changing demand, supply, and market structures create new planning and operational challenges.

All applications to this topic must:

- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Clearly define the merit of the proposed innovation compared to competing approaches and the anticipated outcome, emphasizing the commercialization potential of the overall effort including Phase I and Phase II.
- Applications should provide a path to scale up in potential Phase II follow on work.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and experimental data.

Grant applications are sought in the following subtopics:

a. Convergent Smart Grid Communications and Application Architecture

The embedded platforms for communications and applications that serve the sensors and controllers deployed in the electric grid at present are numerous and fragmented. Solutions are often optimized to the available hardware (e.g., silicon chipset) and may target only vendor-specific platforms. They are often rigid and specialized in terms of the embedded software implementation. Meanwhile, technology suppliers keep delivering cheaper and more capable communications technologies and faster and more functional embedded hardware and software platforms. As a result, new applications and other value additions are highly limited once a communication platform is deployed for an initial set of solutions desired. Since these devices and systems can be long lived, it is important to be able to continue deriving additional value through new applications. Embedded platforms that maintain flexibility at multiple levels, especially as the "internet of things" grows for the energy sector, is vital for grid modernization.

Proposals should identify a mechanism/architecture to abstract smart grid communications and applications from the embedded hardware and software platforms. Proposals should consider the following characteristics:

- Backward compatibility - Application developers should not have to worry about the longevity of the operating system and whether it will be supported in the future
- Sandboxed embedded environment

    - Full firewall capabilities at the grid edge or other open environments using an open source code base (e.g., Linux) that can be evaluated and managed by traditional IT approaches
    - Applications should have the ability to be isolated from others; one application bug need not impact other applications
    - Supports competitive "after-market" application development and is resistant to vendor "lock-in"
- Openness - Sensor and controller manufacturers should not have to rely solely on their internal organizations or a specific vendor to create new applications or to extend applications to find further value.
- Security – Should meet any security configuration with full firewall capabilities. In addition, DTLS (or TLS), IPSec, Netfilter and various VPN clients could be considered.
- Supports peer-to-peer communications and accommodates simpler communications due to greater intelligence at the grid edge.
- Supports various power management frameworks (e.g., plugged-in, battery)

Questions – Contact: Christopher Irwin, christopher.irwin@hq.doe.gov

b. Next Generation Connectors for Cables and Conductors

The 642,000 miles of high-voltage lines and 6.3 million miles of distribution lines that make up the U.S. electric grid are predominantly overhead conductors; however underground cables are also used in strategic locations. Closely associated with cables and conductors are connectors that provide the necessary mechanical and electrical coupling between adjacent power line segments. Compression connectors for overhead lines are made by crimping a soft aluminum sleeve onto the two ends of conductors to be joined. These connectors are basically the weak links in the electricity delivery network, where power transmission can be limited by the connector resistance and disruptions can occur owing to mechanical failures. As electrical loads on existing transmission lines have increased, the performance and integrity of aging connectors continue to degrade due to accelerated surface oxidation from environmental exposure and elevated operating temperatures.

Proposals should identify next generation connector designs (for cables or conductors) with enhanced mechanical and electrical connectivity, as well as resistance to oxidation and other failure mechanisms. Additional material and design considerations include:

- Embedded sensing and diagnostics capabilities
- Improved mechanical strength at elevated temperatures
- Corrosion resistance at elevated temperatures
- Higher electrical conductivity for lower losses
- Ease of installation and recovery after a failure

Questions – Contact: Kerry Cheung, kerry.cheung@hq.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The Office of Energy Efficiency and Renewable Energy (EERE) is at the center of creating the clean energy economy today. EERE leads the U.S. Department of Energy's efforts to develop and deliver market-driven solutions for energy-saving homes, buildings, and manufacturing; sustainable transportation; and renewable electricity generation.

The EERE mission is to strengthen America's energy security, environmental quality, and economic vitality in public-private partnerships to enhance energy efficiency and productivity; bring clean, reliable and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life. EERE's role is to invest in high-risk, high-value research and development that is critical to the nation's energy future and would not be sufficiently conducted by the private sector acting on its own. EERE Technology Office efforts directly support the President's Climate Action Plan goals of doubling renewable electricity generation by 2020 and doubling energy productivity by 2030. On September 17, 2014, U.S. Secretary of Energy Moniz announced a partnership with the Council on Competitiveness and the Alliance to Save Energy to launch Accelerate Energy Productivity 2030 to grow our economy while reducing our energy costs.

EERE's Technology Offices all have multiyear plans, detailed implementation processes and have demonstrated impressive results. To access this information for a particular office, click here.
Program activities are conducted in partnership with the private sector (including small businesses), state and local governments, DOE national laboratories, and universities. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices.
For additional information regarding EERE's priorities, click here.

9. ADVANCED MANUFACTURING

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 Advanced Manufacturing Office (AMO) (www1.eere.energy.gov/manufacturing/) partners with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States.

Grant applications are sought in the following subtopics:

a. Technology for the US Petroleum Refining Industry

Refining of crude oil to fuel and chemical feedstock is the largest industrial energy consuming sector, and refined fuel is the highest energy intensive product of all manufactured products (that is, energy consumed per volume or mass of product). Clearly small gains in energy efficiency within any of the numerous petroleum refining processes have the potential to provide large gains in energy savings; for example, a 1% increase in catalytic cracking efficiency will result in saving some ten million barrels of oil per year in the USA.

This solicitation focuses on new technology development to be commercialized within the petroleum refining industry for improved refining process efficiency. Small business has the opportunity to partner with big business to develop new energy efficiency technology for application within the primary petroleum refining processes.

Areas of particular interests include:

i. New sources of hydrogen for refining processes: Increased emphasis on low sulfur fuels has led to the need for sources of refinery hydrogen in addition to the traditional sources of refinery hydrogen such as the catalytic reforming of straight-chain paraffins to napthene fractions. Refiners typically purchase additional process hydrogen from industrial gas suppliers that produce hydrogen by methane reforming. Technology to supply hydrogen for refinery processes from unconventional hydrogen sources such as VGO and still gases that can be applied directly within the refinery is solicited.

ii. Refinery Catalyst Development: All chemical conversions within refinery processes use catalysts, and R&D of new catalysts to be applied with the US petroleum refining processes is solicited including catalytic cracking of residual distillate to gasoline, catalytic reforming, isomerization, hydro desulfurization and demetalation, and acid catalysts used in the production of reformulated fuels. Responsive grant applications will demonstrate a significant advance of proposed catalyst performance over state of the art catalysts commercially available.

iii. Technology to improve refinery separation efficiencies: The largest single energy burden in a refinery is crude distillation, and R&D of new technology to reduce that energy burden is solicited. This includes technology to be applied in crude distillation units directly such as heat integration technology, membrane separation processes to be used in conjunction with crude distillation, as well as the development of new processes that make use of catalytic distillation. Phasing out of MTBE as blended fuel oxygenate left refineries with unused catalytic distillation capacity, and R&D of new technology for the use of that capacity in the production of fuels or chemical feedstock is solicited.

iv. Process sensors and controls: Sensors and controls represent a cost-effective means of improving efficiency, and R&D for new sensors or controls or both for process and plant wide control of refinery processes is solicited. State of the art of refinery sensor and control technology has to be examined carefully and possible energy savings benefits quantified.

Questions – Contact: Brian Valentine, Brian.Valentine@ee.doe.gov

b. Natural Gas and Manufacturing

The recent emergence of new supplies of natural gas in the U.S. provides an common-sense opportunity to achieve the Nation's energy goals and support domestic prosperity. This enhanced natural gas supply can foster the feedstock and fuel substitution possibilities for natural gas in industry, and with the use of more efficient technologies can contribute to greater competitiveness in U.S. manufacturing [1]. It is projected that significant volumes of natural gas can continue for years into the future to be developed in the U.S. at prices 3 to 4 times lower than that projected for

oil [2]. Point-of-use, on-demand production systems in miniaturized chemical processing systems could offer improved environmental and safety benefits [3]. For this to occur there is a need for low cost, modular process technologies that overcome economy of scale economics and mitigate demonstration risks [4]. Plasma reforming of natural gas offers the opportunity for process intensification [5]. Proposals are sought to develop novel thermal and non-equilibrium (also called cold plasma) reactors for manufacture of valuable products from natural gas. Selective conversion is sought to produce useful products such as acetylene, carbon black, or high performance carbon materials The focus is on reactor development so existing pathways to integration of any necessary catalysts should be clearly demonstrated in the proposal. Novel processes must show improvements to yield, selectivity, and economics compared to state-of-the art technology.

Questions – Contact: Brian Valentine, Brian.Valentine@ee.doe.gov

c. Energy-Water Nexus

Remote or isolated communities, especially those that are located far away from main transportation routes, require that resources and supplies must be shipped in to sustain the community. This presents large logistical issues for these populations in their generation of power and production of potable water. In some instances, they may generate electricity using significant amounts of fossil fuel that has to be transported to that location. This electricity may also be used to desalinate water for drinking and other purposes.

A solution that significantly reduces or eliminates the need for transporting water and fuel to these locations would allow these facilities to become secure and self-sufficient while reducing greenhouse gas emissions. This opportunity solicits designs integrating low carbon emission generation of electricity and energy efficient desalination for potable water production. Designs and bench scale systems in the Phase I application should be scalable to a subsequent Phase II prototype.

Possibilities include, but are not limited to: wind, solar, biomass, geothermal and/or heat recovery used in conjunction with desalination technologies, such as reverse osmosis, flash distillation, forward osmosis, membrane distillation, or dewvaporation that can meet or beat current reverse osmosis cost (~\$1/m^3), as well as energy requirements (>2 kWh/m^3) and/or carbon emissions (>1 kg CO_2/m^3). Proposed technologies and systems should be able to produce fresh water (<500 ppm total dissolved solids) from seawater (35,000 ppm total dissolved solids). Designs that store water and schedule water desalination based on the availability of energy resources are encouraged. For renewable energy planning purposes, applicants can assume that the system will be sited at San Clemente Island.

Questions – Contact: David Forrest, David.Forrest@ee.doe.gov

d. Atomically Precise Structures and Devices for Catalysis

Advances in the design and synthesis of atomically-precise enzyme-like catalytic structures offer the potential for efficient transformation of low-cost chemicals to high value products [1-4]. We seek atomically precise approaches to advance catalyst technology. For the purpose of this opportunity, the term “atomically precise” is defined as virtually defect-free structures and devices, where every atom and bond is at a specified location and orientation, and there are essentially no impurities or

defects in the functional portions. This includes but is not limited to Spiroligomers, Metal Organic Frameworks, engineered proteins, enzymes, ribozymes, and engineered DNA and RNA. While nanoparticles may act as useful substrates for atomically precise catalysts, note that most nanoparticles are not atomically precise and therefore would not qualify as enzyme-like catalytic structures without significant modification or new synthetic approaches for their manufacture. "Enzyme-like" refers to the fact that enzymes have evolved highly-efficient receptor sites and potential energy surfaces to bring chemical reactants together in favorable positions and orientations. The method of synthesis of these atomically precise catalytic structures should allow scalable, high yield production as in most commercial synthetic chemistry processes. We seek applications of high energy impact at a national level.

Areas of particular interests include:

Novel Catalytic Routes to Direct Synthesis of Carbon Fiber from Gas or Solution Phase. As a deliverable, a minimum of 25% improvement in energy intensity over fiber production in current commercial practice shall be demonstrated through the physics-based design and synthesis of atomically precise solid catalysts, with sufficient experimental measurements and supporting calculations to show that the technology could feasibly synthesize low defect carbon fiber, and that cost-competitive energy savings could be achieved with practical economies of scale. The application should provide a path to demonstration of synthesis of carbon fiber (if not actual synthesis), and to process scale up in potential Phase II follow on work.

Photocatalysis of water without using sacrificial reagents. Proposed approaches should require less than half the energy consumption of best-in-class systems (e.g, NaTaO3:La) for equivalent production of H2 and O2.

Low temperature production of chemicals from hydrocarbons. Proposed methods should result in energy consumptions that approach the practical minima outlined in [5].

Questions – Contact: David Forrest, David.Forrest@ee.doe.gov

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10. BIOENERGY

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**

Biomass is a clean, renewable energy source that can significantly diversify transportation fuels in the United States. The U.S. Department of Energy's Bioenergy Technologies Office (BETO) (http://energy.gov/eere/bioenergy) is helping to transform the nation's renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower. BETO is focused on forming partnerships with key stakeholders to develop, demonstrate, and deploy technologies for advanced biofuels production from lignocellulosic and algal biomass.

All applications to this topic must:

- Be consistent with and have performance metrics (whenever possible) linked to BETO's recently updated Multi-Year Program Plan (MYPP) that is available for download directly at: http://energy.gov/eere/bioenergy/downloads/bioenergy-technologies-office-multi-year-program-plan-july-2014-update

- Clearly define the proposed application, the merit of the proposed innovation, and the anticipated outcome with a special emphasis on the commercialization potential of the overall effort including Phase I and Phase II;

- Applications should provide a path to scale up in potential Phase II follow on work.

- Include quantitative projections for price and/or performance improvement that are tied to representative values included in the MYPP or in comparison to existing products. For example, projections of price or cost advantage due to manufacturing improvements, materials use, or design simplification should provide references to current practices and pricing to enable informed comparison to present technologies.

- Demonstrate commercial viability with a quantifiable return on DOE investment as described elsewhere in this FOA.

- Fully justify all performance claims with thoughtful theoretical predictions or experimental data.

a. Design and Fabrication of Solids Handling for Biomass Conversion Systems

Lack of continuous solids handling is one of the main barriers to continuous operation of biomass conversion systems. Robust handlers are needed to continuously move biomass feedstock from ambient conditions into a controlled reactor environment. Grant applications are sought for designs, prototype equipment, and procedures that enable continuous biomass solids handling at 10% lower cost than currently available. The continuous handling into a controlled reactor environment must meet the in-feed specifications of the conversion technology Examples of in-feed specifications are located in two design reports [1,2]. Consideration will be given to ideas that allow for multiple feedstocks, easy manufacturability (including use of non-specialized construction materials), or other features that would enable feedstock from ambient conditions to be continuously moved into the reactor environment used by multiple conversion technology providers.

Questions – Contact: Mark Elless, mark.elless@ee.doe.gov

b. Liquefaction of Wet Organic Waste Streams using Sub- and Supercritical Fluids

Hydrothermal Liquefaction (HTL) of Wet Organic Waste (WOW) streams using subcritical water to produce biofuels and bioproduct precursors is a promising technological pathway.[1] Eligible feedstocks are:

- Biosolids from municipal wastewater treatment plants;
- Organic wastes from industrial processes, such as food and beverage production;
- Residential and commercial food wastes; and,
- Manure slurries from animal husbandry operations.

Projects that utilize algae, even if grown on wastewater, and dry waste streams, such as corn stover, will be considered non-responsive. Proposals that produce syngas, ethanol, or methanol as a final product will also be considered non-responsive, although all of those substances are acceptable as process intermediates. While BETO is already active in this area, this subtopic solicits additional proposals that utilize the following substances as solvents/reactive participants:

1. Subcritical water;[2, 3]
2. Supercritical water,[4-6] or;
3. Sub- or supercritical organic liquids, including supercritical CO2 .[7]

Other organic substances are also welcomed as solvents, provided that they provide a net benefit in greenhouse gas reduction or cost advantages versus traditional waste disposal alternative such as incineration or landfilling. In all cases, the goal is to produce biofuels and bioproduct precursors that align with BETO's 2017 and 2022 cost targets, as articulated in the office's Multi-Year Program Plan.[8] Preference will be given to applications that propose a full chain of production for drop-in biofuels, and articulate a clear and credible path to market. Proposals that include co-products, particularly replacements for petrochemical feedstocks, in order to improve their techno-economic argument are especially welcomed. Net biogenic carbon and overall energy balances will also be key evaluation criteria; submissions that consume more energy than they produce (in terms of HHV present in biofuel products) will be considered non-responsive.

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

c. Co-utilization of CO2 and CH4 to Produce Biofuel and Bioproduct Precursors

Biogas is primarily comprised of methane and carbon dioxide. BETO seeks projects to convert the combination of biogenic CO2 and CH4 into higher hydrocarbons (defined for purposes of this solicitation as C3 and above, or C2 and above with at least one double bond). Proposals that produce syngas, ethanol, or methanol as a final product will be considered non-responsive, although all of those substances are acceptable as process intermediates. For purposes of this subtopic, options include, but are not limited to:

1. Biologically-based conversions;[1-6]
2. Thermo- and electrochemically based processes, which may include microbial components,[7-9] and;
3. Dry (utilizing CO2) reforming of methane.[10-12]

This solicitation seeks applications that utilize combinations of CO2 and CH4 feedstocks to produce biofuels and bioproduct precursors. Evaluation criteria will include the conversion efficiency of biogenic carbon, total energy balance of the proposed processes, and cost-effectiveness in terms of BETO's 2017 and 2022 strategic targets.[13] While biogas from wet organic waste streams is the primary target of this subtopic, proposals that utilize CO2 streams from other sources may be within scope, provided that they utilize non-photosynthetic biological conversion mechanisms. While the primary goal of this solicitation is to further the development of drop-in biofuels from wet organic waste streams, proposals that include biochemical precursors as part of the overall value proposition are welcomed.

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

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11. BUILDINGS

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**

DOE's Building Technologies Office (BTO) advances building energy performance through the development and promotion of efficient, affordable, and high impact technologies, systems, and practices. BTO's 2020 goal is to reduce buildings' energy use by 30%, compared to 2010 "Energy Star" technologies. To secure these savings, research, development, demonstration, and deployment of next-generation building technologies in both the commercial and residential buildings sector are needed to advance building systems and components that are cost-competitive in the market. Energy efficient lighting has enormous potential to conserve energy and enhance the quality of our commercial, industrial and residential building inventory. Electric lighting now consumes ~1/10th of the primary energy delivered annually in the U.S., representing ~22% of the electricity produced. As building envelopes become increasingly airtight to minimize thermal loads, technologies and sensors to manage indoor air quality become increasingly important for occupant health. BTO is dedicated to promoting the widespread and effective use of these technologies to meet its R&D goals.

Grant applications are sought in the following subtopics:

a. Energy Efficient Solid-State Lighting Luminaires, Products, and Systems

The DOE has estimated that advancing energy efficient electric lighting in U.S. buildings could conserve more than 50% of lighting energy with corresponding savings in electricity costs to building operators. These technologies also could reduce utility generation costs with reductions in load, especially during peak consumption. Although SSL sales increase annually, industry stakeholders generally acknowledge that even higher rates of growth and attendant energy conservation are possible by developing and promoting advanced SSL luminaire designs, components, controls and systems that take full advantage of the unique performance capabilities of emerging SSL technology. This is the subject of the present technical topic.

All applications to this subtopic must:

- Be consistent with and have performance metrics linked to the 2015 DOE SSL Research and Development (R&D) Plan whenever possible. [1]

- Clearly define the proposed application, the merit of the proposed innovation, and the anticipated outcome with a special emphasis on the commercialization potential of the overall effort, including Phase I and Phase II.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in the R&D plan or in comparison to existing products. [2] For example, projections of price or cost advantage due to manufacturing improvements, materials use, or design simplification should provide references to current practices and pricing to enable informed comparison to present technologies.
- Demonstrate commercial viability with a quantifiable return on DOE investment.
- Fully justify all performance claims with thoughtful theoretical predictions or experimental data.

SSL Luminaires – Today, SSL luminaires are widely available in an array of direct source replacements and in common lamp replacements such as A-line lamps, PAR lamps, and small linear fluorescent lamps or compact fluorescent lamps. [2] Luminaire designs are available with integrated SSL sources in flat panel architectures that directly replace wall sconces, decorative and safety lighting products and in suspended ceiling luminaires. New, novel and highly energy efficient designs are sought in any of these product areas that build on the unique performance attributes of the SSL source to achieve significant improvements in overall luminaires or lamp performance while achieving the highest possible lighting quality. Applications are sought for designs that are revolutionary, imaginative, impactful, and that will have a significant and lasting effect on increasing SSL market share and energy conservation in the North American general illumination market. Designs that are already under development or that represent incremental or evolutionary improvements over current products are not of interest under this topic.

SSL Components, contributing materials, constituents or integral products – Many individual components and materials (for advanced optoelectronic device packaging/manufacturing) are used in the manufacture of SSL including highly-engineered intermediate products. These components include power supplies, current spreading devices, out-coupling enhancement lenses, and specialty materials such as index matching silicones and epoxies. Applications are sought for replacements or alternatives to these intermediate components, materials, or constituents that could significantly advance the performance of SSL products while simultaneously reducing cost or manufacturing complexity. Such intermediate dedicated products might be part of a thermal management solution, optical delivery and management architecture, power supply, or some other aspect of a modern, energy efficient SSL design. Successful applications should represent innovative, high performance and cost-competitive alternatives. Incremental or evolutionary advancements to existing materials, constituents, or intermediate products are not of interest.

SSL Systems – One of the most important performance attributes of SSL is their direct current (DC) operation, which makes them inherently compatible with digital controls, sensors (e.g. motion sensors, occupancy sensors, ambient light intensity and quality sensors) and DC renewable energy sources such as solar photovoltaic modules. Self-commissioning lighting control systems that easily accommodate variations in interior décor or seasonal adjustments in lighting quality are examples of how novel integration and digital controls may be able to conserve lighting energy much more easily with SSL than with most traditional light sources. Advanced controls and digital features could accelerate the market penetration of various SSL luminaires or lamps by adding valued features not presently available with traditional sources. BTO therefore seeks novel system designs or integrated product concepts that represent both novelty and innovation in concept as well as demonstrable lighting energy conservation potential.

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

b. Technologies for Sensing and Managing Indoor Air Quality in Buildings

As buildings become increasingly airtight, management of indoor air quality becomes increasingly important. BTO seeks to identify technologies to improve indoor air quality, as defined in the specific subtopic descriptions below. Preference will be given to technology solutions that are applicable to the existing building stock. While feasibility studies are appropriate for Phase I funding, applications for these subtopics should be able to exhibit sufficient potential for commercial application in Phase II to be considered for further funding. If selected for further funding, BTO will strongly encourage applicants to include a strategy for obtaining manufacturing partners by the end of Phase II as a part of their commercialization plan.

All applications to this subtopic should:

- Provide quantitative analysis, with all assumptions clearly stated, supporting the performance and economic targets for the proposed technology.
- Specify the intended market(s) for the technology and justify the improved performance relative to existing technologies within that market.
- Clearly define the proposed application of the technology, the merit of the proposed innovation, and the anticipated outcome of the overall effort including Phase I and Phase II.
- Demonstrate commercial viability with a quantifiable return-on-DOE-investment as described elsewhere in this FOA.
- Demonstrate a clear commercialization and production pathway. In addition to established partnerships, this can also include planned activities and strategies to identify and develop a manufacturing or demonstration partner, connect with national laboratory deployment leads, work with stakeholder networks, etc.

Specific areas of interest are:

Energy efficient and affordable radon reduction equipment for residential buildings – Radon is the second leading cause of lung cancer after active smoking and the leading cause among nonsmokers. [3] EPA recommends taking active steps to remove radon in homes with levels at 4 picocuries per liter (pCi/L) or higher, [4] which becomes increasingly common as building envelopes get more airtight. The objective of this topic is to develop the next generation of energy efficient and affordable radon reduction equipment for existing residential buildings. Approaches of interest include improvements to current fan designs, new fan designs and configurations, and other retrofit approaches to mitigate radon. BTO is not interested in radon resistant new construction (RRNC) solutions with this topic.

Applications must meet the following requirements:

Next-Generation Radon Fans	
Requirements	Targets
Performance	Reduction in energy consumption by a minimum of 25% compared to state-of-the-art units. Fan-based devices should

	include performance curves based on laboratory testing under ideal conditions using AMCA 210 (chart: static pressure ins wg vs volume cfm).
Physical size	< 5% larger than state-of-the-art designs
Installation costs	Little to no added installation costs compared to existing systems used today
Required cleaning intervals, or difficulty of cleaning, to maintain as-new performance	Little to no increase as compared to state-of-the-art designs
Susceptibility to damage or corrosion or performance degradation during manufacture, assembly, transportation, installation, or use (indoor and outdoor environments)	Little to no increase as compared to state-of-the-art designs for relevant applications; indoor and outdoor applications.
Lifetime	Same as current units
Cost	Little to no increase as compared to state-of-the-art designs. Projects should have a simple payback period no greater than 5 years at full commercial production rates.

Accurate, stable humidity sensors – Many existing humidity sensors do not maintain accuracy over extended periods of time due to improper water vapor absorption that results from exposure to airborne contaminants or condensation on their surface that can affect their functionality [5]. To enable humidity monitoring and control applications, BTO is looking for new humidity sensors with the ability to remain accurate within ±5% with a long-term stability of ±1% for a period of at least 10 years at installed costs similar to that of current commercially available sensors. Approaches of interest include both new sensing materials and fabrication approaches as well as integrated devices that meet the requirements above. BTO is not interested in sensing approaches that are not compatible with digital controls.

Accurate sensors for indoor air quality – Existing devices for monitoring indoor air quality in residential buildings are too expensive to achieve widespread use. [6] BTO is interested in developing low-cost sensors and integrated devices for radon, carbon monoxide, carbon dioxide, VOCs, and other pollutants relevant to the indoor air environment. Approaches of interest include both sensors and monitoring systems that can be produced at substantially lower cost than existing commercially available devices with comparable or better accuracy. BTO is not interested in approaches that could not be used in conjunction with demand control ventilation strategies.

Questions – Contact: Mohammed Khan, mohammed.khan@ee.doe.gov

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12. FUEL CELLS

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 Energy Efficiency and Renewable Energy's Fuel Cell Technologies Office (FCTO) (http://www1.eere.energy.gov/hydrogenandfuelcells) works in partnership with industry (including small businesses), academia, and DOE's national laboratories to establish fuel cell and hydrogen energy technologies as economically competitive contributors to U.S. transportation needs. A roadmap for the development of fuel cell and hydrogen technologies that guides FCTO investments aimed at lowering the related risks and costs can be found here: http://energy.gov/eere/fuelcells/fuel-cell-technologies-office-multi-year-research-development-and-demonstration-plan.

The office's portfolio focuses on both fuel cell research and development (R&D) and hydrogen fuel R&D, with an emphasis on renewable pathways, delivery, and storage of hydrogen, to meet cost and performance goals. Near term efforts in real-world demonstration and validation help to accelerate market growth and provide critical feedback for future R&D. The portfolio also addresses a number of non-technical factors, such as user confidence, ease of financing, the availability of codes and standards, and helping to enable the establishment of a refueling infrastructure, particularly for fuel cell electric vehicles.

a. TECHNOLOGY TRANSFER OPPORTUNITY: Durable, High Activity Electrocatalyst with Low Platinum Content and Low Cost for Polymer Electrolyte Membrane Fuel Cell Applications

Conventional polymer electrolyte membrane (PEM) fuel cell technology requires high content of platinum electrocatalyst, which raises manufacturing costs. In addition, the platinum catalysts also suffer from marginal durability due to corrosion at the high operating potentials characteristic of fuel cell operation. These shortcomings are particularly acute for the oxygen reduction reaction (ORR) catalysts at the fuel cell cathode. They are barriers to the widespread adoption of fuels cells, and overshadow the technology's benefits in efficient, clean chemical-to-electrical energy conversion. The Fuel Cell Technologies Office (FCTO) has funded Brookhaven National Laboratory (BNL) to develop ORR catalysts with significantly improved oxygen-reduction catalytic activity and reduced platinum loading.

Researchers at BNL have developed an ultralow-platinum electrocatalyst design that significantly decreases the platinum content of the cathode by an order of magnitude while maintaining cathode performance. In addition, the advances have led to improved durability of the ORR catalyst and improved electrode design for fuel cell ORR cathodes. The BNL method uses an advanced core-shell catalyst design in which catalytically active platinum monolayers are deposited on stable nanoparticle cores of palladium or palladium alloys to form Pd@Pt nanocatalysts that enhance Pt specific activity and raise Pt mass activity, as well as overall Platinum Group Metal mass activity. The BNL-produced catalysts incorporated into a fuel cell cathode and integrated into a full membrane electrode assembly (MEA) have higher PGM mass activity than a standard Pt catalyst and greatly improved durability under potential cycling up to 100,000 cycles and even to 200,000 cycles for cores of Pd:Au alloy.

Applications are sought that meet the critical need for core-shell electrocatalyst manufacturing processes for PEM fuel cell MEA components. Awardees must develop a plan to scale-up production of the core-shell Pd@Pt and/or Pd:Au@Pt ORR nanocatalysts, incorporate those catalysts into MEAs, and test the performance and durability of the MEAs under realistic fuel cell operating conditions, including potential cycling to simulate fuel cell use in start-stop driving. Awardees must develop a commercialization plan for Pd@Pt nanocatalysts that would include but is not limited to the manufacture of MEAs incorporating the BNL-designed catalysts for fuel cell vehicle and stationary applications. The work that is envisioned between the SBIR/STTR grantee and BNL would involve Technical Transfer of BNL IP on core-shell catalysts (U.S. Patents 7,691,780, 7,855,021, 9,005,331, 9,034,165, 20130264198). Foreign rights to this IP are not available.

Licensing Information:

BNL Contact: Poornima Upadhya (pupadhya@bnl.gov; 631-344-4711)

Patent Status:
The following patents and patent application are only available for non-exclusive licensing.

- 7,691,780: 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=7691780.PN.&OS=PN/7691780&RS=PN/7691780
- 7,855,021: 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=7855021.PN.&OS=PN/7855021&RS=PN/7855021
- 9,005,331: 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=9,005,331.PN.&OS=PN/9,005,331&RS=PN/9,005,331
- 9,034,165: 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=9034165.PN.&OS=PN/9034165&RS=PN/9034165
- 20130264198: http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.html&r=1&f=G&l=50&s1=%2220130264198%22.PGNR.&OS=DN/20130264198&RS=DN/20130264198

Questions – Contact: Nancy Garland, Nancy.Garland@ee.Doe.Gov or Bahman Habibzadeh, Bahman.Habibzadeh@ee.Doe.Gov

b. Magnetocaloric Materials Development

Magnetocaloric materials (MCMs) have great potential to lower the energy consumption and carbon footprint of technologies used in building cooling, refrigeration, and gas liquefaction (e.g. in the liquefaction of hydrogen or natural gas). MCMs exhibit reversible temperature changes upon magnetization. When subjected to a varying magnetic field these materials undergo a change to the alignment of their magnetic fields which adsorbs or releases energy. MCMs can therefore be layered and integrated with heat transfer fluids to serve cooling applications in a highly efficient manner. The active magnetic generator concept was first introduced in 1982 and significant progress has been made (a). Recent experimental results have measured an achieved 400W of cooling power at a temerpature span of 1.5K for a COP of 1.62 (b). Still, magnetocaloric cooling systems are challenged by high capital cost, difficulty in scaling to commercial sizes, and difficulties in system integration. The high capital costs of these systems is largely attributable to the large quantities of magnets required to effect sufficient changes in temperature and the cost of the MCM materials which traditionally contain a large about of Gadolinium.

Accordingly, research is needed on the development of novel magnetocaloric materials that optimize the following properties at the working temperatures of the intended applications:

1. Adiabatic temperature change (ΔTad) and magnetic entropy change (ΔSm) upon a given magnitude of variation in the magnetic field
2. Susceptibility to hysteresis
3. Mechanical durability during cycling
4. Resistance to corrosion
5. Cost and use of elements that are not critical or rare

Phase I proposals on this topic are sought which include: 1) synthesis of a magnetocaloric material that optimizes the properties listed above within a temperature range relevant for hydrogen gas liquefaction, and 2) characterization of the material's key properties (e.g. ΔTad and ΔSm in a given magnetic field, particle size, sphericity, thermal conductivity, efficiency, and density). Applicants should identify the state of the art and quantify the expected improvement based on their work.

Questions – Contact: Erika Sutherland, erika.sutherland@ee.doe.gov

c. TECHNOLOGY TRANSFER OPPORTUNITY: H2 Safety Sensors for H2 Infrastructure Applications

There is an increasing need for H2 safety sensors as the H2 infrastructure is being built around the world to accommodate fuel cell vehicles. These safety sensors need to have sufficient sensitivity to H2 (< 1%) with a fast response time (< 1 min), minimal cross-sensitivity and long-term durability all at a price point that is much less than is presently available in the marketplace. Currently there are no low cost reliable sensor technologies that can meet all requirements. Many of the issues preventing widespread adoption of best-available hydrogen sensing technologies today outside of cost, derive from excessive false positives and false negatives arising from unstable sensor baseline. The liabilities surrounding present technologies also demand frequent calibration, which drives up operational costs. Los Alamos National Laboratory (LANL) has developed a unique class of electrochemical sensors that can meet all the requirements for H2 safety sensors in infrastructure

applications. These mixed-potential electrochemical sensors are ceramic-based devices manufactured using a unique LANL design that improves their sensitivity while increasing long-term durability. LANL in collaboration with its partners has also developed commercial manufacturing methods to mass-produce these sensors and the necessary electronics/communication packaging to deploy these sensors.

The H2 safety sensors have been extensively evaluated both in the laboratory and at independent test sites. Currently the technology has been deployed at a H2 Fueling station in California where the sensor has proved superior to a commercially available sensor. The newly developed sensor was able to detect leaks associated with the routine vehicle filling operation that were below the detection limit and response time of the commercial sensor. Moreover, the sensor exhibited exceptional stability with no false positives over the month of real time testing. The field-testing of this sensor technology is currently being expanded to include 3 more sensor units at more fueling stations in California to increase the operational database and to further refine sensor electronics.

The work that is envisioned between the SBIR/STTR grantee and LANL would involve Technical Transfer of LANL IP on thin film mixed potential sensor (U.S. Patent 7264700) and associated know-how for H2 sensor manufacturing and packaging.

In Phase-I we expect the grantee to focus on the following:

- Develop low cost electronics packaging manufacturable at high volume
- Integrate LANL sensor into a commercial package that can meet the codes and standards for being deployed at a H2 fueling station

Los Alamos National Laboratory Information:
The following patent is only available for non-exclusive licensing.
TTO tracking numbers: S100, 655, US Patent # 7,264,700,

Contact: Mariann Johnston, 505-667-4391 mjohnston@lanl.gov,

Questions – Contact: Charles (Will) James Jr., Charles.James@EE.DOE.Gov

REFERENCES:

Subtopic a:

1. Sasaki, K., et al, (2012), Highly stable Pt monolayer on PdAu nanoparticle electrocatalysts for the oxygen reduction reaction, Nature Communications, Vol. 3, Article 1115. http://www.nature.com/ncomms/journal/v3/n10/full/ncomms2124.html

2. Sasaki, K., et al, (2010) Core-Protected Platinum Monolayer Shell High-Stability Electrocatalysts for Fuel-Cell Cathodes, Angewandte Chemie Int. Ed., Vol. 49 (46), 8602-8607. http://onlinelibrary.wiley.com/doi/10.1002/anie.201004287/abstract

3. Sasaki, K., et al, (2010), Recent advances in platinum monolayer electrocatalysts fo oxygen reduction reaction: Scale-up synthesis, structure and activity of Pt shells on Pd cores, Electrochimica Acta, Vol. 55 (8), 2645-2652. http://www.sciencedirect.com/science/article/pii/S0013468609015138

4. Adzic, R. R., et al, 2007, Platinum Fuel Cell Electrocatalysts, Topics in Catalysis, Vol. 46 (3), 249-262. http://link.springer.com/article/10.1007/s11244-007-9003-x

5. Zhang, J., et al, 2004, Platinum Monolayer Electocatalysts for O2 Reduction: Pt Monolater on Pd(111) and on Carbon-Supported Pd Nanoparticles, Journal of Physical Chemistry B, Vol. 108 (30), 10955-10964. http://pubs.acs.org/doi/abs/10.1021/jp0379953

Subtopic b:

1. Barclay, J.A., 1982, Use of a ferrofluid as a heat-exchange fluid in a magnetic refrigerator. J. Applied Physics, Vol. 53, 2887-2894. http://scitation.aip.org/content/aip/journal/jap/53/4/10.1063/1.331069

2. Lozano, J.A., et al, 2013, Performance analysis of a rotary active magnetic refrigerator, J. Applied Energy, Vol. 111, 669-680. http://www.sciencedirect.com/science/article/pii/S0306261913004406

Subtopic c:

1. Brosha, E., et al, 2015, Hydrogen Safety, Codes and Standards: Sensors, LANL. http://www.hydrogen.energy.gov/pdfs/review15/scs004_brosha_2015_o.pdf

2. Brosha, E., et al, 2014, Hydrogen Safety, Codes and Standards: Sensors, LANL. http://www.hydrogen.energy.gov/pdfs/progress14/viii_3_brosha_2014.pdf

3. P. K. Sekhar, J. Zhou, M. B. Post, L. Woo, W. J. Buttner, W. R. Penrose, R. Mukundan, C. R Kreller, R. S Glass, F. H Garzon, and E. L Brosha, 2014, Independent testing and validation of prototype hydrogen sensors, International Journal of Hydrogen Energy, Vol. 39(9), 4657-4663. http://www.sciencedirect.com/science/article/pii/S0360319913031923

4. P. K. Sekhar, E. L. Brosha, R. Mukundan, M. A. Nelson, T. L. Williamson, and F. H. Garzon, 2010, Development and testing of a miniaturized hydrogen safety sensor prototype, Sensors and Actuators B: Chemical, Vol. 148 (2), 469-477. http://www.sciencedirect.com/science/article/pii/S0925400510004399

13. SOLAR

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 Energy Efficiency and Renewable Energy's SunShot Initiative (SunShot) (http://energy.gov/eere/sunshot/sunshot-initiative) is working in partnership with industry, academia, national laboratories, and other stakeholders to achieve subsidy-free, cost-competitive solar power by 2020. The potential pathways, barriers, and implications of achieving the SunShot Initiative price reduction targets and resulting market penetration levels are examined in the SunShot Vision Study (http://energy.gov/eere/sunshot/sunshot-vision-study).

In this topic, SunShot seeks applications for the development of innovative and impactful technologies in the areas of:

(a) Controls and Systems for the On-Site Consumption of Solar Energy
(b) Shared Solar Energy Development Tools

Applications may be submitted to any one of the categories listed above but all applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. SunShot targets and/or state of the art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or relevant experimental data

Grant applications are sought in the following subtopics:

a. Controls and Systems for the On-Site Consumption of Solar Energy

For solar energy to reach ubiquitous deployment, building owners, developers, and utilities will need improved capabilities to consume solar on-site, with as little impact on the electric grid as possible. Such an arrangement would reduce costs and technical challenges related to enabling bidirectional power flows, greatly reduce state policy risk, and maximize the value of solar systems' production.

Applications are sought for the development of innovative design tools, controls, and systems that integrate solar PV production, building load controls, electric vehicles and/or stationary storage. Applications should seek to optimize the usage, storage and deployment of solar electricity, while reducing installed costs. Areas of interest include, but are not limited to: (1) automated and predictive analytics applied to building load controls; (2) automated design tools for the development of integrated PV generation, load controls, electric vehicles and/or stationary storage, (3) intelligent controls for the charging and discharging of storage systems; (4) techniques and methods for incorporating short-term weather projections; (5) rapid, efficient, and safe installation of behind-the-meter storage, controls, and generation; and (6) techniques and methods for monetizing integrated PV, load response, and storage in electricity markets.

Questions – Contact: solar.sbir@ee.doe.gov

b. Shared Solar Energy Development Tools

Shared solar has the potential to dramatically expand deployment of solar and increase access to families and organizations who have historically been unable to go solar. Yet the space has yet to fully develop with homeowners, community groups, developers, and utilities lacking the tools and knowledge needed to efficiently market, develop, and monetize the benefits of shared solar.

Applications are sought to develop useful new software and technologies to expand access to shared solar projects. Areas of interest include, but are not limited to: (1) development of new platforms that reduce the cost of customer acquisition for shared solar hosts and participants; and (2) data collection, billing, and project management automation.

Questions – Contact: solar.sbir@ee.doe.gov

14. VEHICLES

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**

EERE's Vehicle Technologies Office (VTO) (www1.eere.energy.gov/vehiclesandfuels/) focuses on reducing the cost and improving the performance of vehicle technologies that can reduce petroleum dependency, including advanced batteries, electric traction drive systems, lightweight materials, advanced combustion engines, and advanced fuels and lubricants. VTO supports the development and deployment of advanced vehicle technologies, including advances in electric vehicles, engine efficiency, and lightweight materials. Since 2008, the Department of Energy has reduced the costs of producing electric vehicle batteries by more than 50%. DOE has also pioneered better combustion engines that have saved billions of gallons of petroleum fuel, while making diesel vehicles as clean as gasoline-fueled vehicles.

Applications that duplicate research already in progress will not be funded; all submissions therefore should clearly explain how the proposed work differs from other work in the field.

Grant applications are sought in the following subtopics:

a. Electric Drive Vehicle Batteries

Applications are sought to develop electrochemical energy storage technologies which support commercialization of micro, mild, and full HEVs, PHEVs, and EVs. Some specific improvements of interest include, but are not limited to, the following: new low-cost materials; high voltage and high temperature non-carbonate electrolytes; improvements in manufacturing processes, speed, or yield; novel SEI stabilization techniques for silicon anodes; improved cell/pack design minimizing inactive material; significant improvement in specific energy (Wh/kg) or energy density (Wh/L); and improved safety. Applications must clearly demonstrate how they advance the current state of the art and meet the relevant performance metrics listed at www.uscar.org/guest/article_view.php?articles_id=85.

When appropriate, the technology should be evaluated in accordance with applicable test procedures or recommended practices as published by the Department of Energy (DOE) and the U.S Advanced Battery Consortium (USABC). These test procedures can be found at www.uscar.org/guest/article_view.php?articles_id=86. Phase I feasibility studies must be evaluated in full cells (not half cells) greater than 200mAh in size while Phase II technologies should be demonstrated in full cells greater than 2Ah. Applications will be deemed non-responsive if the proposed technology is high cost; requires substantial infrastructure investments or industry standardization to be commercially viable; and/or cannot accept high power recharge pulses from regenerative breaking or has other characteristics that prohibit market penetration.

Questions – Contact: Brian Cunningham, brian.cunningham@ee.doe.gov

b. SiC MOSFETs for Electric Drive Vehicle Power Electronics

Power electronic inverters are essential for electric drive vehicle operation, and the Vehicle Technologies Office (VTO) has established cost and performance targets that need to be met so that these vehicles can decouple personal mobility from oil, cut pollution and help build a 21st Century American automotive industry that will lead the world. Specifically, inverter R&D targets and research pathways have been outlined by DOE in both the U.S. DRIVE partnership Electrical and Electronics Technical Team Roadmap [1] and EV Everywhere Blueprint [2]. Both of these technical documents specifically address the performance benefits of WBG semiconductors, but their current high cost is a barrier to high volume automotive adoption.

With large area (> 150 mm, or 6") Silion Carbide (SiC) epitaxial wafer availability from a large number of qualified suppliers, the SiC device industry is approaching the state of the cost-competitive silicon (Si) power device industry, where the cost of fabrication is the primary driver for device cost, and their high device yield allows for a low overall cost of devices.
Devices crucial for vehicle inverters which can take advantage of these SiC epitaxial wafers, SiC switches with either built-in free-wheeling Schottky diodes (lower cost) or in conjunction with Schottky diodes, offer significantly smaller on-state resistance as compared to current Si switches and enable very high power density, modular inverters for use in electric drive vehicles. The extremely high speed of SiC switches also allows for increased efficiencies and reduced passive device requirements for power inverter applications. While lower current (<50A) SiC switches offered by few SiC device suppliers have already penetrated solar and computer power supply manufacturers, the capability to handle currents > 100 A remains a key threshold for automotive applications.

This topic seeks to address this barrier through demonstrating the successful production of > 100A, > 600V rated switches with either built-in Schottky diodes (lower cost) or used with external Schottky diodes suitable for use in electric drive vehicle traction motor inverters. Specifically, devices produced should show automotive application readiness through passing qualification specifications or standards and high yields. Where possible, applicants should show a relationship to, and demonstrate an understanding of, automotive application requirements and environments. Examples include surface and/or substrate treatments and processing, and compatibility with existing power module packaging and processing. Proposals should also describe the cost of manufacturing SiC switches compared to competing Si switches, including details such as costs and availability of commercial SiC substrates, epi-layers, and additional equipment needed. These costs should be linked to a commercially viable business model for large scale manufacturing and should approach cost parity with Si switches on a cost per amp basis.

Questions – Contact: Steven Boyd, steven.boyd@ee.doe.gov

c. Reduction of PGM Loading in Automotive Emission Control Systems

Modern automotive emission control catalyst systems utilize monolithic flow-through supports coated with high surface area inorganic oxides and, typically, platinum group metals (PGMs). These metals - palladium, platinum and rhodium - are suspended in the washcoat, a refractory oxide layer

bonded to a ceramic or metal support surface. The North American market has the most stringent emissions regulations for the passenger car sector. The tightening of emissions standards has placed an ever-greater burden on catalyst performance and compliance has come in part through higher PGM content with associated higher costs and market volatility risks.

Strategies are sought for reducing PGM loading in automotive catalyst systems through new techniques for dispersing the PGMs in the washcoat or through complete or partial substitution of PGMs with other, lower cost catalytic materials. Applications may include oxidation catalysts and three-way catalysts for gasoline engines, NOx adsorbers for lean-burn gasoline engines, as well as oxidation catalysts, urea selective catalytic reduction and NOx adsorbers for diesel engines.

The prototype catalyst thrifting strategy developed under this subtopic must be capable of reducing PGM loading by 50% in the proposed automotive emission control system application with conversion performance and durability comparable to current production catalyst systems. (For reference, the average loading for three-way catalysts is 1.1 grams PGM per liter of engine displacement).

Questions – Contact: Ken Howden, ken.howden@ee.doe.gov

d. Variable Compression Ratio or Variable Stroke Internal Combustion Engine With Real-Time Controllability

A commercially viable control system design, including hardware and software, is desired for enabling the dynamic control of the compression ratio and/or piston stroke of operating internal combustion engines in passenger vehicles.

Applications for variable compression ratio control should propose the development of systems that:

1. Are viable in current passenger car reciprocating engine architectures;
2. Have a low expected additional cost to implement on an automotive engine;
3. Work reliably for the typical lifetime of an automobile;
4. Allow real-time compression ratio control from approximately 9.0 to 14.0;
5. Are capable of a short response time to control input changes over the desired compression ratio range above – the ability to change compression ratio by at least 0.25 per engine cycle over the entire range;
6. Are compatible with existing automotive engine architectures;
7. Are likely to result in a working prototype implemented on a modern, modified production automotive engine in Phase II.

Applications for variable stroke control should propose the development of systems that:

1. Are viable in current passenger car reciprocating engine architectures;
2. Have a low expected additional cost to implement on an automotive engine;
3. Work reliably for the typical lifetime of an automobile;
4. Allow real-time stroke control from approximately 40% to 100% of the maximum stroke;
5. Are capable of a short response time to control input changes over the desired stroke range above;

6. Are compatible with existing automotive engine architectures;
7. Are likely to result in a working prototype implemented on a modern, modified production automotive engine in Phase II.

Questions – Contact: Leo Breton, leo.breton@ee.doe.gov

e. Alternative Crank Mechanisms for Internal Combustion Engines Leading to Improved Energy Efficiency

Reciprocating internal combustion (e.g. gasoline or diesel) engines for automotive applications use slider/crank mechanisms to create torque on an engine's output shaft from forces applied to pistons as a result of the pressure created by the combustion of fuel. While direct mechanical losses of traditional slider/crank mechanisms are small, there is another indirect loss as a consequence of slider/crank use. Early in an engine's power stroke, cylinder temperatures—and therefore convective and radiative heat losses—all peak. The engine's rate of performing work is still very low reducing energy efficiency. The net effect may be that slider/crank mechanisms indirectly lead to preventable energy losses and reduced energy efficiency.

Applications must propose the development or demonstration of a functioning prototype of a mass-produced, commercially available reciprocating engine, modified with an alternative mechanical mechanism linking the piston to the engine's output shaft is desired. Reporting must include fuel consumption test results over the entire engine map of the prototype compared with a second, unmodified, otherwise identical engine. All fuel consumption testing must be conducted according to engine industry norms. Statistically valid fuel economy improvements (95% confidence level) of at least 4.0% are desired.

Questions – Contact: Leo Breton, leo.breton@ee.doe.gov

REFERENCES:

Subtopic b:

1. U.S. DRIVE Partnership Electrical and Electronics Technical Team Roadmap, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/eett_roadmap_june2013.pdf

2. EV Everywhere Grand Challenge Blueprint, http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_blueprint.pdf

15. WATER

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 Energy Efficiency and Renewable Energy's Wind and Water Technology Office's Water Program seeks applications for innovation in small hydropower, and instream hydrokinetic energy technologies. The Water program (http://energy.gov/eere/water/water-power-program) researches, tests, evaluates, and develops innovative technologies capable of generating renewable,

environmentally responsible, and cost-effective electricity from water resources. This includes hydropower, as well as marine and hydrokinetic energy technologies, which capture energy from waves as well as riverine, tidal, and ocean currents.

Grant applications are sought in the following subtopic:

a. Innovative Very Low-head and Instream Current Water Power Turbine-Generator Technologies

There are a number of studies that show very low head hydropower potential as well as instream hydrokinetic resource potential in the United States. Some of these resource assessments referenced at:
http://energy.gov/eere/water/downloads/assessment-and-mapping-riverine-hydrokinetic-resource-continental-united-stat-0

To harness energy from these resources applications are sought for innovative modular and water power turbine-generator (unit) technologies that can be rapidly deployed and retrieved with a useable life of around 20 years. Both hydropower technologies and in-stream hydrokinetic technologies will be considered. Such technologies should be scalable to generate no less than 50kW power per unit at very low heads of less than 10 feet or instream currents (in rivers, streams, canals or natural and man-made waterways). Please note that ocean current or tidal current technologies are not of interest under this subtopic. Applicants must provide a detailed description of their technology including the following parameters:

1. Type of resource targeted for the technology
2. Minimum and maximum head or the water level difference between the entrance and exit to be used for power generation
3. Minimum and Maximum discharge through the units for power generation
4. Device Rating in terms of kilowatts (kW). This is typically the maximum sustainable power output of a device on a continuous basis without failure. Normally, the peak power rating of a device is greater than the rated capacity
5. Projected unit or device dimensions including weight
6. Type of materials proposed to be used
7. Targeted Levelized Cost of Energy (LCOE) including Annual Energy Production (AEP) and associated resource intensity; assumed useful life; Installation and Operation & Maintenance (IO&M) costs; and unit cost with a justification
8. Modularity and scalable aspects of the technology
9. Environmental acceptability of the technology.

The applicants should also detail how they propose to utilize the grant to advance the technology and if successful, the commercialization potential of the technology.

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov

16. WIND

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 Energy Efficiency and Renewable Energy's Wind Program, part of the Wind and Water Power Technologies Office (www.eere.energy.gov/wind/), seeks applications for innovations that significantly advance the goal of large cost reductions in the deployment of U.S. wind power resources by exploring technologies that enable the production of larger wind turbine rotors through active load alleviation.

Grant applications are sought in the following subtopic:

a. Advancing Technology for Offshore Wind Resource Characterization

Development of a low-cost marine atmospheric boundary layer (MABL) measurement system which could serve as a core element of a buoy-based data collection network for the offshore renewable energy industry is needed. Projects are sought to develop a commercially viable, buoy-based remote sensing technology for MABL characterization for offshore wind applications. Key requirements are that measurements must support profiles of wind speed and direction, temperature, humidity and atmospheric stability up to heights of 200m, with data sampling and communication rates appropriate for advanced rapid refresh weather modeling. In addition, the sensor package size, weight and power consumption should be suitable for deployment on existing met-ocean buoy platforms. The proposed measurement technology should serve as a lower-cost alternative to existing measurement technologies. Applicants are required to justify the economic viability of the proposed package assuming near term (<5 years) industry deployment for project resource characterization.

Questions – Contact: Joel Cline, joel.cline@ee.doe.gov

PROGRAM AREA OVERVIEW: OFFICE OF ENVIRONMENTAL MANAGEMENT

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and

expediently deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

DOE has approximately 91 million gallons of liquid waste stored in underground tanks and approximately 4,000 cubic meters of solid waste derived from the liquids stored in bins. The current DOE estimated cost for retrieval, treatment and disposal of this waste exceeds $50 billion to be spent over several decades. The highly radioactive portion of this waste, located at the Office of River Protection (Hanford Reservation), Idaho, and Savannah River sites, must be treated and immobilized, and prepared for shipment to a future waste repository.

DOE also manages some of the largest groundwater and soil contamination problems and subsequent cleanup in the world. This includes the remediation of 40 million cubic meters of contaminated soil and debris contaminated with radionuclides, metals, and organics [1]. The Office of Groundwater and Soil Remediation focuses on four areas of applied research including the Attenuation-Based Remedies for the Subsurface Applied Field Research Initiative (Savannah River Site), the Deep Vadose Zone Applied Field Research Initiative (Hanford Site), the Remediation of Mercury and Industrial Contaminants Applied Field Research Initiative (Oak Ridge Site), and Advanced Simulation Capability for Environmental Management.

For additional information regarding the Office of Environmental Management priorities, please visit us on the web at http://energy.gov/em/office-environmental-management.

17. NOVEL MONITORING CONCEPTS IN THE SUBSURFACE

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: **NO**	*Accepting STTR Fast-Track Applications:* **NO**

DOE's Environmental Management Program is leading an effort to develop new methods and processes to attenuate contaminants in the subsurface and improve the ability to monitor that attenuation process. The intention is to eliminate costly pump and treat systems as the contaminant levels diminish while assuring the public and regulator community that we are protecting human health and the environment. The following subtopic areas will provide new tools for the site contractors to use in the clean-up process and result in reducing the life cycle cost of subsurface remediation at Savannah River Site (Aiken, SC), Hanford Site (Richland, WA), and Oak Ridge Site (Oak Ridge, TN). Further information can be found on the DOE-EM website under the Office of Groundwater and Soils.

We propose to solicit the best concepts from industry in the following two broad themes:

1. Onsite and Field Monitoring Tools & Sensors
2. Sorbents for Anionic Contaminants

a. Onsite and Field Monitoring Tools and Sensors

Onsite and field tools and sensors to support the monitoring of environmental restoration and D&D activities at mercury contaminated facilities are needed. These tools and sensors are intended to augment and eventually replace incremental laboratory analysis of discrete samples for either characterization or regulatory compliance applications. Example technologies include field analysis sensors, deployed sensors, screening tools and other concepts that provide rapid analysis capabilities thereby substantially reducing the labor for sample collection and time necessary to

complete the analysis, resulting in a significant reduction of the overall cost of monitoring. Viable tools and sensors include those that provide for the direct measurement of constituents or those that use indicator or surrogate parameters. This focus area includes applications relevant to the in-situ detection and monitoring of total mercury and mercury species, including elemental mercury, in water and soil at environmentally relevant concentrations. Deployment strategies should consider applications including monitoring of contaminated outfalls, storm water run-off impacts from D&D activities, and stream mass-flux evaluations under dynamic flow conditions.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

b. Sorbents for Anionic Contaminants

Anionic contaminants in groundwater are emerging as a major driver of future risk within the DOE Complex. In particular, 99Tc and 129I are problems in some existing groundwater contamination plumes, but also are identified in Performance Assessments of nuclear disposal facilities as responsible for much of the future risk via a groundwater pathway. One approach to minimizing risk from these contaminants is development of sorbents or sequestration agents that are robust enough for long-term in situ deployment in environmental conditions such as in permeable reactive barriers. To achieve this, the sorbents should be highly selective for pertechnetate or various iodine species. Alternatively, novel methods of deployment can be developed that protect the sorbent until an indicator of an approaching contamination plume is sensed. For example, "smart" coatings for sorbent particles could be developed that dissolve when exposed to a parameter or constituent that is indicative of the contaminant source.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

c. Other

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

Questions – Contact: Latrincy Bates, Latrincy.bates@em.doe.gov

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PROGRAM OFFICE OVERVIEW: OFFICE OF FOSSIL ENERGY

DOE's Office of Fossil Energy (FE) is responsible for several high-priority initiatives including implementation of the Clean Coal Power Initiative to develop a new generation of environmentally sound clean coal technologies as well as innovations in oil and natural gas technologies to recover oil, natural gas, methane hydrates, and shale gas still obtainable from the Nation's conventional oil reservoirs and/or from non-conventional sources.

Fossil fuels are projected to remain the mainstay of energy consumption (currently 80% of U.S. energy consumption) well into the next century. Consequently, the availability of these fuels, and their ability to provide clean affordable energy, is essential for global prosperity and security. As the nation strives to reduce its reliance on imported energy sources, FE supports R&D to help ensure that new technologies and methodologies will be in place to promote the efficient and environmentally sound use of America's abundant fossil fuels. As the economy expands, and the demand for hydrocarbons increases accordingly, FE seeks to develop advanced fossil energy technologies that are reliable, efficient, environmentally sound and economically competitive.

For additional information regarding the Office of Fossil Energy priorities, visit
http://www.energy.gov/fe/about-us

18. CLEAN COAL AND CARBON 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:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

For the foreseeable future, coal will continue to play a critical role in powering the Nation's electricity generation, especially for base-load power plants. Coal-fired power plants have made significant progress in reducing emissions of sulfur dioxide (SO2), nitrogen oxide (NOx), particulate matter (PM), and recently mercury (Hg), since the passage of the Clean Air Act. Recently proposed limits on CO2 emissions from new electric generating units will require carbon capture on any new coal-fired power plant. To prepare for upcoming regulations, significant research and development is currently being pursued for new technologies to capture carbon from flue gas streams produced by coal-fired electric generating power plants. In addition, the Office of Fossil Energy (FE) is developing a new generation of clean coal-fueled energy conversion systems capable of producing competitively priced electric power while reducing CO2 emissions, with a focus on improving efficiency, increasing plant availability, reducing cooling water requirements, and achieving ultra-low emissions of traditional pollutants. A key aspect of this area of research is targeted at improving overall system thermal efficiency, reducing capital and operating costs, and enabling affordable capture. FE also continues to support research that ensures that CO2 can be safely and permanently stored in geologic formations in a process known as carbon storage.

Particular attention will be focused on finding new ways to extract the power from coal – while simultaneously expanding environmental protection and confronting the issue of global climate change. Key R&D programs include: (1) Crosscutting Technology Research in the area of physics-based models that accurately describe the creep behavior of state of the art and advanced structural alloys under uniaxial stress conditions. (2) Advanced Energy Systems (AES) for future coal-based power plants including separation of solid sorbent/oxygen carrier particles from solid coal contaminants; innovative approaches of additive manufacturing techniques to design and develop gas turbine components; improvement of the economics of bituminous coal use in small coal gasifiers; and development of computational tools capable of predicting compressor performance over a wide range of fluid conditions both in the supercritical and two phase flow regimes. (3) Carbon Capture technologies including conversion techniques for the utilization of CO2 as fuel; and systems improvements methods to reduce carbon emissions at a relative cost below $40 per tonne of CO2. (4) Carbon Storage technologies in the area of wellbore leakage pathway detection techniques.

Grant applications are sought in the following subtopics:

a. Improved Models of Long Term Creep Behavior of High Performance Structural Alloys for Existing and Advanced Technologies Fossil Energy Power Plants (Crosscutting Technology Research)

Design of structural components for FE power plant components that operate in the creep regime of mechanical behavior (high applied stress and temperatures above about 40% of the alloy melting point in absolute temperature units) is normally done on the basis of a minimum 300,000 hours operating life. Most existing FE power plants in the United States (US) were designed for steady state operation in which creep effects alone dominate the mechanical design of high temperature stress bearing components. The average age of US coal fired power plants is over 30 years, and many coal fired plants will be operated in cycling mode with an expectation of another 30 years of life. Cyclic operation results in additional structural material degradation due to thermo-mechanical fatigue. Under certain conditions the combined effect of creep and fatigue can reduce the useful life of high temperature materials beyond the effect of either creep or fatigue by themselves. Weldments of high temperature creep resistant materials are also susceptible to premature failure when subject to the combined effects of creep and thermo-mechanical fatigue.

Advanced FE power generation cycles will operate at temperature and pressure/stress conditions that exceed current commercially operating FE power plants. Examples of advanced FE power generation cycles include, but are not limited to, Advanced Ultrasupercritical (>1300 deg F and >4000 psi steam temperature and pressure) air and oxygen fired pulverized coal power plants, chemical looping combustion, and supercritical CO2. Advanced FE power generation cycles will utilize advanced structural alloys, such as polycrystalline nickel superalloys, and state of the art 9% chrome creep resistant ferritic steels, austenitic steels, and ferro-nickel alloys. These materials are more expensive than the structural alloys used in most existing FE power plants. Design of components that use advanced and state of the art creep resistant structural alloys will utilize finite element modeling (FEM) tools to calculate the long term mechanical behavior and the optimum designs of these components.

A key requirement for more accurate life assessment calculations of FE power plant component in existing plants, and for optimal mechanical design of new components is a physics based mathematical description of the creep behavior (strain evolution versus time as a function of applied stress, temperature and microstructure; and where the model describes extreme conditions, e.g., zero creep strain at zero applied stress, time to creep rupture approaches zero as applied stress approaches ultimate hot tensile stress, creep strain rate approaches zero as operating temperature is reduced) of structural alloys and their weldments. Such models need to be applicable to operating times of at least 300,000 hours, describe creep behavior over the expected range of temperature and applied stresses, account for multi-axial conditions on creep, and be numerically stable when used in FEM simulations of three dimensional (3D) components. For some creep resistant ferritic and stainless steel alloys (e.g., P91 steel and 316 stainless steel) large lab scale uniaxial creep test data exist run to at least 100,000 hours. Some long term plant data is also available.

Applications are sought for physics based models that accurately describe the creep behavior of state of the art and advanced structural alloys or their weldments under uniaxial stress conditions, and to greater than 300,000 hours. Applications should provide the lab and plant data sets that will

be used to develop the creep model, a method to analyze variability in the experimental data, a statistical based measure of goodness of fit of the model(s) to the data set, and a procedure to account for multi-axial stress conditions. Applications can focus on either the base alloy only or weldments of an alloy. An application that focuses on weldments will need to consider the base alloy because the creep behavior of the base alloy will affect the creep behavior of the weldment.

The creep model(s) and numerical algorithm for calculating creep strain vs time developed should be verified and validated using the method described in ASME PTC 60/V&V (Guide for Verification & Validation of in Computational Solids Mechanics). Numerical stability of the computational model should be demonstrated in at least one typical commercially available Finite Element Modeling (FEM) software package that is used for modeling time dependent stresses and strains of solids. Examples of commercially available FEM software are ANSYS and ABAQUS. The programming language of the numerical algorithm of the creep model should be compatible for direct use of the numerical algorithm in commercially available FEM software packages.

Questions – Contact: Rick Dunst at richard.dunst@netl.doe.gov

b. Solid Separation Technology Enabling Sorbent Reuse in Fossil Energy Combustion Applications (AES - Advanced Combustion)

A large segment of fossil energy power generation applications, both conventional and advanced, require injection of particulate sorbents and/or oxygen carriers for successful process operations. Examples include conventional Fluidized Beds Combustors (FBC), Oxygen-fired Pressurized Fluidized Bed Combustors (Oxy-PFBC), and Chemical Looping Combustion (CLC). In FBCs and Oxy-PFBCs, limestone is typically injected for sulfur removal and expelled from the system as a by-product. In CLC, a similar interaction between the oxygen carrier particles and fuel based contaminants can occur. In each case, the net result is that sorbents/carriers are intermingled with contaminants leaving the system that subsequently require landfill disposal.

An opportunity exists to separate the fuel-based contaminants (e.g. char & ash) from sorbents/carriers for beneficial reuse and recycling. Contaminant-free sorbents/carriers may be sold for industrial purposes such as manufacturing wallboard or cement. In other cases, the contaminant-free sorbents/carriers may be reused within the systems themselves. In all cases, landfill disposal costs would be decreased.

Grant applications are sought for technologies suitable for the separation of solid sorbent/oxygen carrier particles from solid coal contaminants. Examples could include but are not limited to: ash separation and unconverted char separation technologies amenable to by-product or recycling streams from fossil energy combustion applications.

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

c. Additive Manufacturing of Gas Turbine Components (AES - Advanced Turbines)

Additive manufacturing (AM), which creates components in a layering manner to achieve intricate final shape products has been identified as an attractive option for the manufacture of high temperature performance components used in gas turbines. AM also offers the design and synthesis of materials from the bottom up, to create multifunctional components wherein the materials,

microstructure and properties enable the performance of multiple functions in addition to enhancing structural integrity. Examples of a multifunctional component include a turbine blade made of a nickel-based superalloy with advanced cooling features; or single-crystal microstructure having a ceramic thermal barrier coating (TBC); or a ceramic-metal matrix composite material on the airfoil tip providing abrasion resistance and oxidation resistance. These components can be engineered over relatively small or large length scales depending upon the functional gradient characteristics desired in competing material property sets.

Grant applications are sought for research and development to explore innovative approaches of the AM techniques to design and develop gas turbine components with functionality and characteristics that can meet or exceed the performance requirements of the current state of the art materials. Approaches of interest include, but are not limited to feasibility of additive manufacturing techniques to create preferred microstructures of a material system that possesses a combination of strength, ductility, thermal stability, and corrosion and wear resistance for high temperature gas turbine applications. The proposed R&D applications should address materials-system level performance concerns such as thermal gradients, thermal expansion mismatch, and interdiffusion/chemical compatibility. The new material systems must withstand the expected temperature cycles. 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. Manufacturing processes or techniques that can be further optimized or perfected relative to creating a more functional part or component are of particular interest. Applications can focus on individual components; however, a clear plan should be presented outlining how entire substrate and coating architectures would be fabricated and implemented and detailing performance expectations.

Questions – Contact: Rin Burke at patcharin.burke@netl.doe.gov

d. Improvements of Bituminous Coal Reaction Kinetics for Fluid Bed or Transport Gasification (AES – Gasification)

FE seeks proposals that will improve the economics of bituminous coal use in small coal gasifiers operating at pressures under 400 psi and optimal temperatures in fluid bed or transport mode operations. This will require increasing the reactivity of bituminous coals. Methods could include smaller particle sizes, feed slurry composition, use of biomass ash or other catalytic agents, methane as a transport gas, alternative energy sources, coal partitioning, or other feed processing, injection or gasification technologies. Since the goal is for the syngas produced to be used for power or transportation fuels, aromatics and hydrogen production are favored, whereas carbon dioxide or methane production would be a liability.

The kinetics of gasification depend on coal particle size. Since, typical particle sizes for entrained flow gasifiers are on the order of 100µm, one possible way to achieve increased coal reactivity is to use coal that has been milled to particle sizes of around 10µm. This increases the total surface area exposed to the gasification environment and is expected to increase the rate of gasification at lower temperatures.

Also, work using biomass ash has been shown to increase coal reactivity; however, particle-particle limits on the catalytic potential remains a challenge.

Technologies amenable to modularization are of special interest to the DOE, as are technologies that could be used effectively at mine-mouth or coal preparation locations.

Questions – Contact: Arun Bose at arun.bose@netl.doe.gov

e. Computational Tools for Predicting Compressor Performance in Supercritical CO2 Power Cycles (AES - Supercritical CO2)

In recent years, supercritical CO2 (SCO2) power cycles have gained significant interest across multiple power generation applications (Renewable, Nuclear, and Fossil Energy). Supercritical CO2 power cycles are anticipated to achieve higher efficiencies than steam-based Rankine cycles at turbine inlet temperatures greater than 550°C. References show that 50% thermal-to-electric conversion efficiency can be achieved from SCO2 power cycles having turbine inlet temperatures exceeding 700°C.

The performance of the compressor/pump in a supercritical CO2 power cycle can have a significant effect on the overall thermodynamic efficiency of the cycle. Most supercritical CO2 power cycle designs propose a compressor that operates very close to the critical point of CO2. Some cycles involve operating the compressor below the critical point where condensation and two-phase flow would occur. Certainly during startup, shutdown or ramping of a supercritical CO2 power cycle, the compressor would be expected to see a wide range of fluid properties where fluid density would be a strong function of pressure and temperature. Currently, computational fluid dynamics codes for compressor design and performance assessment have only limited capability to handle real gasses in an accurate and numerically stable manner. No codes exist which can handle real gasses that are transitioning through the vapor dome and becoming two-phase flows. This subtopic seeks to develop computational tools capable of predicting compressor performance over a wide range of fluid conditions both in the supercritical and two phase flow regimes. The tools would need to be able to handle thermodynamic property input from both real gas laws as well as databases such as NIST RefProp and be able to handle fluid mixtures such as CO2 with impurities such as H2O, CO, Ar and N2. A key feature of the code would be the ability to predict when the onset of two-phase flow occurs so that the user would not be forced to choose a particular fluid property model.

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

f. Utilization: CO2 to fuels - conversion techniques (Carbon Capture)

The conversion of CO2 to a hydrocarbon fuel is an endothermic process. For conversion to result in a net reduction of CO2 emissions, the energy required for the process must come from some other source than the direct combustion of fossil fuels. Approaches are sought that utilize low-quality waste heat, geothermal energy, or direct solar radiation or wind to supply the energy required for conversion. The intermittency of renewable energy sources should be considered in how the proposed technology can be integrated with the power plant. Conversion technologies of particular interest include thermal catalytic, electrochemical and biological based processes. In responding to this subtopic, applicants should demonstrate a thorough understanding of the technology being proposed and the primary process being targeted; including any geographical distribution of the existing industry of interest.

Questions – Contact: Andy Aurelio at isaac.aurelio@netl.doe.gov

g. Carbon Capture Solvent System Improvements (Carbon Capture)

As solvents appear to be a potential option for large-scale carbon capture from coal-fired utilities, several issues remain that will continue to keep this technology suite cost prohibitive. DOE is currently supporting multiple small- and large-scale R&D projects to demonstrate the technical and economic feasibility of carbon capture using a variety of solvent technologies but, many of these solvent systems have similar challenges. While advances have been made to reduce both the capital cost and the regeneration energy penalty, costs from other challenges associated with solvent systems remain a concern. To this end, the DOE is looking to fund research that supports DOE's goals to reduce carbon emissions at a relative cost below $40 per tonne of CO2 in the following 3 areas:

1. Novel mitigation methods to decrease the quantity of aerosols that are formed from solvent systems in the presence of sulfur dioxide, sulfur trioxide and other compounds that exacerbate aerosol formation.
2. Technologies to minimize solvent oxidation reactions in aqueous or non-aqueous solvent systems.
3. Novel reclamation methods that can be applied specifically to aqueous or non-aqueous solvent systems.

Questions – Contact: Andy Aurelio at isaac.aurelio@netl.doe.gov

h. Wellbore Leakage Pathway Detection (Carbon Storage)

The U.S. Environmental Protection Agency (EPA) Underground Injection Control (UIC) regulations for Class VI wells provide guidance for identifying and detecting leaks from wellbores within the regulatory area of review of a CCS project, but does not describe methods to accurately identify why leakage has, or may occur, from existing wellbores (other than the injection well). Advanced methods are needed to characterize the exact mechanisms and pathways by which subsurface fluids may escape through existing wellbores into Underground Sources of Drinking Water (USDWs) or to the surface. Detailed knowledge of leakage pathways is important to devising methods for preventing or remediating leaks. An essential part of ensuring protection of USDWs is the technical capability to characterize potential leakage pathways in existing wellbores.

Grant applications are sought for projects that will advance diagnostic techniques, tools, methods, or protocols to improve current capabilities of identifying potential wellbore leakage pathways. This will lead to improved techniques for prediction, identification, and quantification of leakage characteristics (location, leak flux, and dimensions of leakage pathway) and allow for better quantification of risk from leaky wellbores. Responsive proposals will focus on advanced physical, sonic, optical, and cement bond logging techniques, or multi-dimensional imaging tools that improve the resolution of micro-annuli at interfaces or fracture networks of varying geometries throughout the wellbore and surrounding formation. Of particular interest are technologies capable of characterizing leakage location, flux, and dimensions of leakage pathway in existing boreholes that have been exposed to CO2 or CO2-saturated brine over an extended period (decades). Preference will be given to technologies that demonstrate enhanced performance at reduced cost.

Approaches in developing new or enhancing existing modeling technologies are not of interest for this subtopic. Grant applications using these approaches will not be responsive to the topic.

Questions – Contact: Bruce Brown at bruce.brown@netl.doe.gov

i. Other

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

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

Questions – Contact: Maria Reidpath at maria.reidpath@netl.doe.gov

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19. OIL AND GAS TECHNOLOGIES

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 dramatic increase in domestic natural gas production from shale source rocks is in large part due to the combination of large volume, multistage hydraulic fracturing and horizontal drilling technologies. The increased use of hydraulic fracturing has prompted concerns about the risk of subsurface contamination of potable water supplies, and highlighted the fact that our technologies for understanding precisely the shape and position of created hydraulic fractures remain rudimentary. In addition, while the increase in natural gas production promises the benefit of a significant decrease in the carbon intensity of our domestic energy portfolio, it can do so only so long as the inadvertent emission of methane during the production, gathering and processing portions of the natural gas delivery process is kept to a minimum. Finding better ways to directly monitor "where hydraulic fractures go," and also how to reduce the volume of methane emissions from producing and processing equipment, are two important ways to maximize the positive environmental benefits of increased natural gas production.

DOE is interested in catalyzing the development of novel technologies that will improve our ability to understand much more precisely the dimensions (length, height, and width), orientation (azimuth, dip) relative to the wellbore, and the conductivity and proppant distribution of created hydraulic fractures, either during or immediately after the hydraulic fracturing operation. Our ability to estimate all of these remains limited, and some of the best techniques (e.g., micro-seismic fracture mapping) are expensive, time consuming, and to some degree dependent on the availability of monitoring wells (Cipolla, et al, 2000). DOE is currently funding several projects directly or indirectly related to this topic (e.g., NETL, 2015a,b,c) but believes that there is still a need for more research in this area.

In addition, DOE is interested in funding research that can help companies more cost effectively target and reduce emissions of methane in the production, gathering, processing and compression of natural gas. Recently, the EPA has identified a number of key mechanical elements that contribute a large share of the methane emissions in these areas and proposed new rules for processes and equipment (EPA, 2015). These rules require surveys of key components using optical gas imaging equipment. Equipment elements highlighted for special scrutiny include pneumatic pumps, pneumatic controllers, and centrifugal compressors with wet seal systems, reciprocating compressors, and storage tanks.

Research on major novel advances that can have (or lead to) "game-changing" impacts on hydraulic fracture diagnostics or methane emissions reduction will be considered more responsive to this solicitation than research that proposes small, incremental advances.

Grant applications are sought in the following subtopics:

a. Improving Hydraulic Fracture Diagnostics

This subtopic topic focuses on improving techniques for determining the dimensions, orientation, and conductivity of hydraulic fractures created along horizontal laterals in oil and gas wells drilled in tight formations.

Specific technology interests include:

1. Cost effective tools or methods for measuring the dimensions and/or orientation of hydraulic fractures during or after the hydraulic fracturing process
2. Cost effective tools or methods for measuring the fluid conductivity of hydraulic fractures
3. Cost effective tools or methods for measuring proppant distribution within hydraulic fractures

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

Proposals to fund the development of new (or modification of existing) hydraulic fracturing models will be considered less responsive to the priorities of this solicitation than proposals to fund the development of tools or the demonstration of operating technologies.

Questions – Contact: Albert Yost at albert.yost@netl.doe.gov

b. Improving Methods for Reducing Methane Emissions from Mechanical Components within Upstream Natural Gas Production, Gathering, Processing and Compression Systems

This subtopic focuses on the development and/or testing of technologies, tools or methods for cost-effective detection and/or mitigation of methane emissions from upstream natural gas production, gathering, processing and compression systems.

Specific technology interests include:

1. Tools or methods that can decrease the cost and/or increase the accuracy of optical surveys for detecting methane emissions within natural gas producing systems
2. Tools or methods for decreasing the cost or increasing the effectiveness of mitigating methane emissions from pneumatic pumps, pneumatic controllers, centrifugal compressors, reciprocating compressors, and storage tanks.

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

Questions – Contact: Albert Yost at albert.yost@netl.doe.gov

c. Other

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

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

Questions – Contact: Albert Yost at albert.yost@netl.doe.gov

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Subtopic b:

1. EPA, 2015, Summary of Requirements for Processing and Equipment at natural Gas Production Gathering and Boosting Stations, EPA's Air Rules for the Oil Natural Gas Industry, p.4. http://www3.epa.gov/airquality/oilandgas/pdfs/natgas_prod_summ_081815.pdf

PROGRAM AREA OVERVIEW: OFFICE OF FUSION ENERGY SCIENCES

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

fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. This is accomplished by studying plasma and its interactions with its surroundings across wide ranges of temperature and density, developing advanced diagnostics to make detailed measurements of its properties and dynamics, and creating theoretical and computational models to resolve the essential physics principles. FES has four strategic goals:

- Advance the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source;
- Support the development of the scientific understanding required to design and deploy the materials needed to support a burning plasma environment;
- Pursue scientific opportunities and grand challenges in high energy density plasma science to better understand our universe, and to enhance national security and economic competitiveness, and;
- Increase the fundamental understanding of basic plasma science, including both burning plasma and low temperature plasma science and engineering, to enhance economic competiveness and to create opportunities for a broader range of science-based applications.

This is a time of important progress and discovery in fusion research. The U.S. has joined an international consortium (consisting of the European Union, Japan, China, Russia, Korea, and India) to fabricate and operate the next major step in the fusion energy sciences research program, a facility called “ITER”. The purpose of ITER is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. Experimental operations are planned to begin in approximately 10 years and are expected to continue for 20 years, demonstrating production of at least 10 times the power used to heat the fusion fuel and providing a platform to validate proposed commercial-grade technologies needed for power production.

The FES program is making great progress in understanding turbulent losses of particles and energy across magnetic field lines used to confine fusion fuels, identifying and exploring innovative approaches to fusion power that may lead to more economical power plants and encouraging private sector interests to apply concepts developed in the fusion research program. The following topics are restricted to advanced technologies and materials for fusion energy systems, fusion science, and technology relevant to magnetically confined plasmas, high energy density plasmas and inertial fusion energy, and low-temperature plasmas, as described below.

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

20. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

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**

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and

materials will need to be substantially advanced relative to today's capabilities in order to achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. Further information about research funded by the Office of Fusion Energy Sciences (FES) can be found at the FES Website, http://www.science.energy.gov/fes.

Grant applications are sought in the following subtopics:

a. Plasma Facing Components

The plasma facing components (PFCs) in energy producing fusion devices will experience 5-15 MW/m2 surface heat flux under normal operation (steady-state) and off-normal energy deposition up to 1 MJ/m2 within 0.1 to 1.0 ms. Refractory solid surfaces represent one type of PFC option. These PFCs are envisioned to have a refractory metal heat sink, cooled by helium gas, and a plasma facing surface, consisting of an engineered refractory metal surface or a thin coating of refractory material that minimizes thermal stresses. The materials being considered include tungsten alloys. Grant applications are sought to develop: (1) innovative tungsten alloys having good thermal conductivity , resistance to recrystallization and grain growth, good mechanical properties (e.g., strength and ductility), and resistance to thermal fatigue; (2) coatings or bulk specialized low-Z materials for improved plasma performance; (3) innovative refractory-metal heat sink designs for enhanced helium gas cooling; (4) efficient fabrication methods for engineered surfaces that mitigate the stresses due to high heat flux; and (5) joining methods, for attaching the plasma facing material to the heat sink, that are reliable, efficient to manufacture, and capable of high heat transfer – these new joining techniques may be applicable to either advanced, helium-cooled, refractory heat sinks or present-day, water-cooled, copper-alloy heat sinks.

Another PFC option is to use a flowing liquid metal surface as a plasma facing component, an approach which will require the production and control of thin, fast flowing, renewable films of liquid lithium, gallium, or tin for particle control at diverters. Grant applications are sought to develop: (1) techniques for the production, control, and removal of flowing (velocity 0.01 to 10 m/s) liquid metal films (0.5-5 mm thick) over a temperature controlled substrate; (2) advances in materials that are wetted by liquid metals at temperatures near the respective metal melting point and that are conducive to the production of uniform well-adhered films; (3) techniques for active control of liquid metal flow and stabilization in the presence of plasma instabilities (time and space varying magnetic field).

Questions – Contact: Daniel Clark, daniel.clark@science.doe.gov

b. Blanket Materials and Systems

This topic seeks to address the challenges in harnessing fusion power, and developing the fusion fuel cycle technology through an advanced breeding blanket, which is designed to breed, extract, and process the nuclear fuel and heat energy necessary for a self-sufficient, electricity-generating reactor. The blanket is a complex, multi-function, multi-material engineered system (structure, breeder, multiplier, coolant, insulator, tritium processing), with many scientific and technological issues in need of resolution. Proposals are requested that address the following issues that include but are not limited to:

- Innovative solid fusion breeder fuel materials development and simulation tools;
- Innovative liquid fusion breeder and/or coolant materials development and simulation tools;

- Advanced materials and tools for simulation and analysis of breeder blanket material and component behavior in the fusion nuclear environment including thermofluid, MHD, and thermomechanical simulation of coolant flows and structural responses;
- Innovative materials and tools for simulation and analysis of materials and systems for tritium processes including creation, extraction, separation, purification, management and containment;
- Diagnostic sensors for blanket systems that are compatible with the fusion environment;
- Neutronic simulation and analysis tools that go beyond the current state of the art.

More detail on the topics of interest follow:

Solid breeder material concepts that advance as many as possible of the following criteria: (1) high breeder material densities (up to~80%); (2) high thermal conductivities (as opposed to point contacts between pebbles); (3) better thermal contact, such as reliable joined contact, with cooling structures (instead of point contacts between pebbles and wall); (4) the absence of major geometry changes between beginning-of-life and end-of life (such as sintering in pebble beds) in the presence of high neutron fluence; (5) structural integrity in freestanding and self-supporting structures with significant thermo-mechanical flexibility; (6) high breeding ratios that benefit from increased breeder and multiplier material densities (typically lithium and beryllium) and preferably leverage existing R&D in nano and micro engineered materials, such as those developed for advanced lithium ion batteries; and tools for simulation and analysis of materials and systems for solid breeders that leverage advanced computational techniques.

New liquid breeder material concepts that advance as many as possible of the following criteria: (1) new liquid breeder materials that have a high breeding capacity; (2) that are not influenced by the magnetohydrodynamic (MHD) effect; (3) can operate at high temperatures (400-700 deg C); (4) are not corrosive to the materials used in planned fusion systems (RAFM steels, ODS steels, NFAs, SiC); (5) are conducive to tritium extraction, and tools for simulation and analysis of materials and systems for liquid breeders that leverage advanced computational techniques.

Insulating the flowing liquid metal breeder/coolant against MHD and thermal effects with Flow Channel Inserts (FCI), which support liquid metal breeders. These materials have a low electrical conductivity (1 to 50 Ω-1m-1). FCI structural loading is low, but they must be able to withstand radiation damage and thermal stresses from through-surface temperature differences in the range of 150-300K, over a thickness of 3 to 15 mm depending on designs.

Materials, simulations and tools needed for managing tritium used in the fusion fuel cycle in a safer and more efficient manner are needed. Early experiments can be performed using hydrogen as a surrogate, but more advanced technology development will likely need to be partnered with a national laboratory with the ability to handle tritium. Current solid breeders operate with a He purge gas at approximately 8 MPa, and liquid metal breeders at a partial pressure of approximately 0.3 Pa. Tritium extraction technologies including permeator materials and extraction methods need to distinguish between the different species for more efficient trapping and desorption from the He purge gas that operate at better than 40% efficiency on the first pass. An advanced purification system to remove impurities at better than 90% efficiency on the first pass is needed along with tritium barrier and management materials. An integrated multi-physics simulation tool to model tritium chemistry, tritium transport through materials, permeation rates, tritium concentration and

flux in materials and systems, at different irradiation levels which goes beyond the current state of the art available domestically and internationally.

Diagnostics for the blanket system are needed, including liquid metal flow sensors that are able to accurately measure the velocity profile across the whole cross-section, and tritium concentration sensors.

Neutronic and safety simulation and analysis tools for determining radiation-induced material damage, tritium breeding efficiency, and worker radiation exposure conditions under a fusion environment with a peak 14 MeV neutron source are needed. The fusion neutronic environment is different, and harsher than the fission environment. Simulation and analysis tools that advance the state of the art to enable effective prediction of the fusion Tritium Breeding Ratio (TBR), material damage effects, such as swelling and creep, and prediction of the effectiveness of fusion radiation shields and barriers designed to limit worker and remote handling equipment exposure to the radiation environment, are critical to the safe adoption of fusion power. Ideally these tools are plug-ins, or compatible modules within existing commercial design software codes for structural, thermal, fatigue, or fluid flow, or safety analyses, such as Ansys®, Fluent®, Nastran®, LS-DYNA®, to enhance the integration, validation, and adoption of the tools.

Questions – Contact: Albert Opdenaker, albert.opdenaker@science.doe.gov

c. Superconducting Magnets and Materials

New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems. Of particular interest are magnet components, superconducting, structural and insulating materials, or diagnostic systems that lead to magnetic confinement devices which operate at higher magnetic fields (14T-20T), in higher nuclear irradiation environments, provide improved access/maintenance or allow for wider operating ranges in temperature or pulsed magnetic fields.

Grant applications are sought for:

Innovative and advanced superconducting materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs. Of specific interest are materials such as YBCO conductors that are easily adaptable to bundling into high current cables carrying 30-60 kA. Desirable characteristics include high critical currents at temperatures from 4.5 K to 50 K, magnetic fields in the range 5 T to 20 T, higher copper fractions, low transient losses, low sensitivity to strain degradation effects, high radiation resistance, and improved methods for cabling tape conductors taking into account twisting and other methods of transposition to ensure uniform current distribution.

Novel methods for joining coil sections for manufacture of demountable magnets that allow for highly reliable, re-makeable joints that exhibit excellent structural integrity, low electrical resistance, low ac losses, and high stability in high magnetic field and in pulsed applications. These include conventional lap and butt joints, as well as very high current plate-to-plate joints. Reliable sliding joints can be considered.

Innovative structural support methods and materials, and magnet cooling and quench protection methods suitable for operation in a fusion radiation environment that results in high overall current density magnets.

Novel, advanced sensors and instrumentation for monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); of specific interest are fiber optic based devices and systems that allow for electromagnetic noise-immune interrogation of these parameters as well as positional information of the measured parameter within the coil winding pack. A specific use of fiber sensors is for rapid and redundant quench detection. Novel fiber optic sensors may also be used for precision measurement of distributed and local temperature or strain for diagnostic and scientific studies of conductor behavior and code calibration.

Radiation-resistant electrical insulators, e.g., wrap able inorganic insulators and low viscosity organic insulators that exhibit low gas generation under irradiation, less expensive resins and higher pot life; and insulation systems with high bond and higher strength and flexibility in shear.

Questions – Contact: Barry Sullivan, barry.sullivan@science.doe.gov

d. Structural Materials and Coatings

Fusion materials and structures must function for a long time in a uniquely hostile environment that includes combinations of high temperatures, reactive chemicals, high stresses, and intense damaging radiation. The goal is to establish the feasibility of designing, constructing and operating a fusion power plant with materials and components that meet demanding objectives for safety, performance, and minimal environmental impact.

Grant applications are sought for:

Development of innovative methods for joining beryllium (~2 mm thick layer) to RAFM steels. The resulting bonds must be resistant to the effects of neutron irradiation, exhibit sufficient thermal fatigue resistance, and minimize or prevent the formation of brittle intermetallic phases that could result in coating debonding.

Development of fabrication techniques for typical component geometries envisioned for use in test blanket modules for operation in ITER using current generation RAFM steels. Such fabrication techniques could include but are not limited to appropriate welding, hot-isostatic pressing, hydroforming, and investment casting methods as well as effective post joining heat treatment techniques and procedures. Appropriate fabrication technologies must produce components within dimensional tolerances, while meeting minimum requirements on mechanical and physical properties.

Development of oxide dispersion strengthened (ODS) ferritic steels. Approaches of interest include the development of low cost production techniques, improved isotropy of mechanical properties, development of joining methods that maintain the properties of the ODS steel, and development of improved ODS steels with the capability of operating up to ~800˚C, while maintaining adequate fracture toughness at room temperature and above.

Development of functional coatings for the RAFM/Pb-Li blanket concept. Coatings are needed for functions that include (1) compatibility: minimizing dissolution of RAFM in Pb-Li at 700°C, (2) permeation: reducing tritium permeation (hydrogen for demonstration) by a factor of >100 and (3) electrically insulating: reducing the pressure drop due to the magneto-hydrodynamic (MHD) effect. Proposed approaches must: (1) account for compatibility with both the coated structural alloy and liquid metal coolant for long-time operation at 500-700˚C (2) address the potential application of candidate coatings on large-scale system components; and (3) demonstrate that the permeation and MHD coatings are functional during or after exposure to Pb-Li.

Priority will be given to innovative methods or experimental approaches that enhance the ability to obtain key mechanical or physical property data on miniaturized specimens, and to the micromechanics evaluation of deformation and fracture processes.

Questions – Contact: Daniel Clark, daniel.clark@science.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: Barry Sullivan, barry.sullivan@science.doe.gov

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1. U.S. Department of Energy Office of Fusion Energy Sciences. (2009). Research Needs for Magnetic Fusion Energy Sciences. Report of the Research Needs Workshop (ReNeW). Bethesda, Maryland. June 8-12, 2009. http://science.energy.gov/~/media/fes/pdf/workshop-reports/Res_needs_mag_fusion_report_june_2009.pdf

2. U.S. Department of Energy Office of Science: Fusion Energy Sciences Advisory Committee. (2012). Opportunities for Fusion Materials Science and Technology Research now and During the ITER Era. http://science.energy.gov/~/media/fes/pdf/workshop-reports/20120309/FESAC-Materials-Science-final-report.pdf

Subtopic b:

1. U.S. Department of Energy Office of Fusion Energy Sciences. (2009). Research Needs for Magnetic Fusion Energy Sciences. Report of the Research Needs Workshop (ReNeW). Bethesda, Maryland. June 8-12, 2009. pp. 285-292. http://science.energy.gov/~/media/fes/pdf/workshop-reports/Res_needs_mag_fusion_report_june_2009.pdf

2. U.S. Department of Energy Office of Science: Fusion Energy Sciences Advisory Committee. (2012). Opportunities for Fusion Materials Science and Technology Research now and During the ITER Era. http://science.energy.gov/~/media/fes/pdf/workshop-reports/20120309/FESAC-Materials-Science-final-report.pdf

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21. FUSION 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:* **NO**
Accepting STTR Phase I Applications: **YES**	*Accepting STTR Fast-Track Applications:* **NO**

The Fusion Energy Sciences program currently supports several fusion-related experiments with many common objectives. These include expanding the scientific understanding of plasma behavior and improving the performance of high temperature plasma for eventual energy production. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts for (a) measuring magnetized-plasma parameters, (b) for low-temperature and multi-phase plasmas, (c) for magnetized-plasma simulation, control, and data analysis, and (d) for overcoming deleterious plasma effects during discharges. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector. Further information about research

funded by the Office of Fusion Energy Sciences (FES) can be found in the FES website at http://science.energy.gov/fes/.

Grant applications are sought in the following subtopics:

a. Diagnostics

Diagnostics are key to advancing our ability to predict and control the behavior of fusion plasmas. Applications are sought for the development of advanced diagnostic techniques to enable new way of studying plasma behavior, or to measure plasma parameters not previously accessible, or at a level of detail greater than previously possible, or at a substantially reduced cost or complexity, and for the development needed in applying existing diagnostics to new, relatively unexplored, or unfamiliar plasma regimes or scenarios. Development of diagnostics meeting needs for advancing the science of boundary and pedestal physics, explosive instability (including ELMs and disruptions), and long-pulse magnetized plasmas are particularly welcome. Development leading to dramatic reduction in the cost of particle accelerators (e.g. MEMS-based accelerators) suitable for use as a diagnostic for magnetic fusion experiments are encouraged, as well as new detectors and associated technologies to work with these accelerators as a diagnostic system. Requests seeking funding for the routine application or operation of proven and matured diagnostic techniques at the major fusion facilities will not be considered under this subtopic. Such diagnostic applications are typically funded via separate solicitations as part of experimental facilities, based on their own research program priorities.

Questions – Contact: Francis Thio, francis.thio@science.doe.gov

b. Components for Heating and Fueling of Fusion Plasmas

Grant applications are sought to develop components related to the generation, transmission, and launching of high power electromagnetic waves in the frequency ranges of Ion Cyclotron Resonance Heating (ICRH, 50 to 300 MHz), Lower Hybrid Heating (LHH, 2 to 10 GHz), and Electron Cyclotron Resonance (or Electron Bernstein Wave) Heating (ECRH / EBW, 28 to 300 GHz). These improved components are sought for the microwave heating systems of the fusion facilities in the United States and facilities under construction including ITER. Components of interest include power supplies, high power microwave sources or generators, fault protection devices, transmission line components, and antenna and launching systems. Specific examples of some of the components that are needed include tuning and matching systems, unidirectional couplers, circulators, mode convertors, windows, output couplers, loads, energy extraction systems from spent electron beams and particle accelerators, and diagnostics to evaluate the performance of these components. Of particular interest are components that can safely handle a range of frequencies and increased power levels.

For the ITER project, the United States will be supplying the transmission lines for both the ECRH (2 MW/line) system, at a frequency of 170 GHz, and for the ICRH system (6 MW/line), operating in the range of 40 – 60 MHz.. For this project, grant applications are needed for advanced components that are capable of improving the efficiency and power handling capability of the transmission lines, in order to reduce losses and protect the system from overheating, arcing, damage or failure during the required long pulse operation (~3000s). Examples of components needed for the ECRH transmission line include high power loads, low loss miter bends, polarizers, power samplers, windows, switches, and dielectric breaks. Examples of components needed for the ICRH

transmission line include high power loads, tuning stubs, phase shifters, switches, arc localization methods, and in line dielectric breaks. For the ECRH and ICRH ITER transmission lines, improved techniques are needed for the mass production of components, in order to reduce cost. Lastly, advanced computer codes are needed to simulate the radiofrequency, microwave, thermal, and mechanical components of the transmission lines.

Questions – Contact: Barry Sullivan, barry.sullivan@science.doe.gov

c. Simulation and Data Analysis Tools for Magnetically Confined Plasmas

The predictive simulation of magnetically confined fusion plasmas is important for the design and evaluation of plasma discharge feedback and control systems; the design, operation, and performance assessment of existing and proposed fusion experiments; the planning of experiments on existing devices; and the interpretation of the experimental data obtained from these experiments. Developing a predictive simulation capability for magnetically confined fusion plasmas is very challenging because of the enormous range of overlapping temporal and spatial scales; the multitude of strongly coupled physical processes governing the behavior of these plasmas; and the extreme anisotropies, high dimensionalities, complex geometries, and magnetic topologies characterizing most magnetic confinement configurations.

Although considerable progress has been made in recent years toward the understanding of these processes in isolation, there remains a critical need to integrate them in order to develop an experimentally validated integrated predictive simulation capability for magnetically confined plasmas. In addition, the increase in the fidelity and level of integration of fusion simulations enabled by advances in high performance computing hardware and associated progress in computational algorithms has been accompanied by orders of magnitude increases in the volume of generated data. In parallel, the volume of experimental data is also expected to increase considerably, as U.S. scientists have started collaborations on a new generation of overseas long-pulse superconducting fusion experiments. Accordingly, a critical need exists for developing data analysis tools addressing big data challenges associated with computational and experimental research in fusion energy science.

Grant applications are sought to develop simulation and data analysis tools for magnetic fusion energy science addressing some of the challenges described above. Areas of interest include: (1) verification and validation tools, including efficient methods for facilitating comparison of simulation results with experimental data; (2) methodologies for building highly configurable and modular scientific codes and flexible user-friendly interfaces; (3) tools for creating interfaces to legacy codes; and (4) remote collaboration tools that enhance the ability of geographically distributed groups of scientists to interact and collaborate in real-time.

The simulation and data analysis tools should be developed using modern software techniques, should be capable of exploiting the potential of current and next generation high performance computational systems, and should be based on high fidelity physics models. The applications submitted in response to this call should have a strong potential for commercialization and should not propose work that is normally funded by program funds. Although applications submitted to this topical area should primarily address the simulation and data analysis needs of magnetic fusion energy science, applications proposing the development of tools and methodologies which have a broader applicability, and hence increased commercialization potential, are encouraged.

Questions – Contact: John Mandrekas, john.mandrekas@science.doe.gov

d. Components and Modeling Support for Validation Platforms for Fusion Science

Small-scale plasma research experiments in the FES program have the long-term performance measure of demonstrating enhanced fundamental understanding of magnetic confinement and improving the basis for future burning plasma experiments. This can be accomplished through investigations and validations of the linkage between prediction and measurement for scientific leverage in testing the theories and scaling the phenomena that are relevant to future burning plasma systems. This research includes investigations in a variety of concepts such as stellarators, spherical tori, and reversed field pinches. Key program issues include initiation and increase of plasma current; dissipation of plasma exhaust power; symmetric-torus confinement prediction; stability, continuity, and profile control of low-aspect-ratio symmetric tori; quasi-symmetric and three-dimensional shaping benefits to toroidal confinement performance; divertor design for three-dimensional magnetic confinement configurations, and the plasma-materials interface. Grant applications are sought for scientific and engineering developments, including computational modeling, in support of current experiments in these research activities, in particular for the small-scale concept exploration experiments. The proposed work should have a strong potential for commercialization. Overall, support of research that can best help deepen the scientific foundations of understanding and improve the tokamak concept is an important focus area for grant applications.

Questions – Contact: Sam Barish, sam.barish@science.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: Barry Sullivan, barry.sullivan@science.doe.gov

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22. HIGH ENERGY DENSITY PLASMAS AND INERTIAL FUSION ENERGY

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**

High-energy-density laboratory plasma (HEDLP) physics is the study of ionized matter at extremely high density and temperature, specifically when matter is heated and compressed to a point that the stored energy in the matter reaches approximately 100 billion Joules per cubic meter (the energy density of a hydrogen molecule). This corresponds to a pressure of approximately 1 million atmospheres or 1 Mbar. Research in HEDLP forms the scientific foundation for developing scenarios that could facilitate the transition from laboratory inertial confinement fusion (ICF) to inertial fusion energy (IFE).

While substantial scientific and technical progress in inertial confinement fusion has been made during the past decade, many of the technologies required for an integrated inertial fusion energy system are still at an early stage of technological maturity. This relative immaturity ensures that commercially viable IFE remains a long-term (>15 years) objective. Research and development activities are sought which address specific technology needs (specified below), necessary to both assess and advance IFE. Given the long-term prospects for IFE, applications submitted under this topical area must also clearly describe their potential/plans for short-term (2-10 years) commercialization in other commercial industries such as telecommunications, biomedical, etc.

Grant applications are sought in the following subtopics:

a. Driver Technologies

Inertial fusion energy hinges on the ability to compress an ICF target in tens of nanoseconds and repeat this process tens of times per second. Thus, the development of technologies is needed to build a driver (e.g., lasers, heavy-ions, pulsed power) that can meet the IFE requirements for energy on target, efficiency, repetition rate, durability, and cost. Specific areas of interest include but are not limited to: wavelength and beam quality for lasers, brightness for lasers and heavy ions, and pulse shaping and power.

Questions – Contact: Curt Bolton, curt.bolton@science.doe.gov

b. Ultrafast Diagnostics

The development of ultrafast diagnostics is needed to assess driver and plasma conditions on sub-picosecond time scales. This technology has the potential to enable the development and deployment of feedback systems capable of ensuring the necessary reliability required for commercially viable IFE.
Specific areas of interest include but are not limited to the generation, detection, and control of nonlinear optical processes in plasmas.

Questions – Contact: Curt Bolton, curt.bolton@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: Curt Bolton, curt.bolton@science.doe.gov

REFERENCES:

1. Advancing the Science of High Energy Density Laboratory Plasmas. Report of the High Energy Density Laboratory Plasmas Panel of the Fusion Energy Sciences Advisory Committee. January 2009. http://science.energy.gov/~/media/fes/fesac/pdf/2009/Fesac_hed_lp_report.pdf

23. LOW TEMPERATURE PLASMAS

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**

Low-temperature plasma science and engineering addresses research and development in partially ionized gases with electron temperatures typically below 10 eV. This is a field that accounts for an enormous range of practical applications, from light sources and lasers to surgery and making computer chips, among many others. The commercial and technical value of low temperature plasma (LTP) is well established where much of this benefit has resulted from empirical development. As the technology becomes more complex and addresses new fields, such as energy and biotechnology, empiricism rapidly becomes inadequate to advance the state of the art. Predictive capability and improved understanding of the plasma state becomes crucial to address many of the intellectually exciting scientific challenges of this field.

Building upon fundamental plasma science, further developments are sought in plasma sources, plasma surface interactions, and plasma control science that can enable new plasma technologies or marketable product and impact in other areas or disciplines leading to even greater societal benefit. The focus is on utilizing fundamental plasma science knowledge and turning it into new applications.
Use of readily available LTPs involving very little plasma science in a direct application of another field will not be considered. All research proposals must have a strong commercialization potential.

Grant applications are sought in the following subtopics:

a. Low-Temperature Plasma Science and Technology for Biology and Biomedicine

One of the current challenges identified in the areas of biological and medical applications of low-temperature plasmas is improving our current understanding and scientific knowledge in the area of plasma-biomatter interactions. Specific examples include but are not limited to: plasma-based bacterial inactivation, cancer cell modification, etc.

Questions – Contact: Curt Bolton, curt.bolton@science.doe.gov

b. Low-Temperature Plasma Science and Engineering for Plasma Nanotechnology

Another current challenge has been identified in plasma assisted material synthesis for improving our current understanding and scientific knowledge in the area of plasma nanotechnology. Specific examples include but are not limited to: plasma-based nanotubes, submicron matters, etc.

Questions – Contact: Curt Bolton, curt.bolton@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this topic including plasmas separation technology, plasma assisted combustion and fuel generation, and MHD power generation.

Questions – Contact: Curt Bolton, curt.bolton@science.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF HIGH ENERGY PHYSICS

Through fundamental research, scientists have found that all observed matter is composed of apparently point-like particles, called leptons and quarks. These constituents of matter were created following the "big-bang" that originated our universe, and they are components of every known object that exists today. We also understand a great deal about the four basic forces of nature: electromagnetism, the strong nuclear force, the weak nuclear force, and gravity. For example, in the past we have learned that the electromagnetic and weak forces are two components of a single force, called the electro-weak force. This unification of forces is analogous to the unification in the mid-nineteenth century of electric and magnetic forces into electromagnetism. History shows that, over a period of many years, the understanding of electromagnetism has led to many practical applications that form the technical basis of modern society.

The goal of the Department of Energy's (DOE or the Department) Office of High Energy Physics (HEP) is to provide mankind with new insights into the fundamental nature of energy and matter and the forces that control them. This program is a major component of the Department's fundamental research mission. Such fundamental research provides the necessary foundation that enables the nation to advance its scientific knowledge and technological capabilities, to advance its industrial competitiveness, and possibly to discover new and innovative approaches to its energy future.

The DOE HEP program supports research in three discovery frontiers, namely, the energy frontier, the intensity frontier, and the cosmic frontier. Experimental research in HEP is largely performed by university and national laboratory scientists, usually using particle accelerators located at major laboratories in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago, IL. The Department also has a significant role in the Large Hadron Collider (LHC) at the CERN laboratory in Switzerland. The Tevatron Collider at Fermilab was the world's highest energy accelerator for over a decade, until the startup of the LHC. The Fermilab complex also includes the Main Injector, which is used independently of the Tevatron to create high- energy particle beams for physics experiments, including the world's most intense neutrino beam. The SLAC National Accelerator Laboratory and the Lawrence Berkeley National Laboratory are involved in the design of state-of-the-art accelerators and related facilities for use in high-energy physics, condensed matter research, and related fields. SLAC facilities include the three kilometer long Stanford Linear Accelerator capable of generating high energy, high intensity electron and positron beams. The first two kilometers of the linear accelerator are currently being used for the Facility for Advanced Accelerator Experimental Tests (FACET). While much progress has been made during the past five decades in our understanding of particle physics, future progress depends on a great degree of availability of new state-of-the-art technology for accelerators, colliders, and detectors operating at the high energy and/or high intensity frontiers.

Within HEP, the Advanced Technology subprogram supports the research and development required to extend relevant areas of technology in order to support the operations of highly specialized accelerators, colliding beam facilities, and detector facilities which are essential to the goals of the overall HEP program. As stewards of accelerator technology for the nation, HEP also supports development of new concepts and capabilities that further scientific and commercial needs beyond the discovery science mission. The DOE SBIR program provides a focused opportunity and mechanism for small businesses to contribute new ideas and new technologies to the pool of knowledge and technical

capabilities required for continued progress in HEP research, and to turn these novel ideas and technologies into new business ventures.

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

24. ADVANCED CONCEPTS AND TECHNOLOGY FOR PARTICLE ACCELERATORS

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 High Energy Physics (HEP) program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. The strategic plan for HEP includes initiatives on the energy and intensity frontiers, relying on accelerators capable of delivering beams of the required energy and intensity. As high energy physics facilities get bigger and more costly, the DOE HEP program seeks to develop advanced technologies that can be used to reduce the overall machine size and cost, and also to develop new concepts and capabilities that further scientific and commercial needs beyond HEP's discovery science mission.

In many cases the technology sought is closely tied to a specific machine concept which sets the specifications (and tolerances) for the technology. Applicants are strongly encouraged to review the references provided. Applications to subtopics specifically associated with a machine concept that do not closely adhere to the specifications of the machine will be considered non-responsive.

For subtopics that are not machine-specific, applicants are strongly advised to understand the state-of-the-art and to clearly describe in the application what quantitative advances in the technology will result.

The subtopics are grouped into the following categories:

- Advanced Accelerator Concepts (subtopics a-h)
- Computational Tools and Simulation of Accelerator Systems (subtopics i-k)
- Particle Beam Sources (Electron and Ion) (subtopics l-m)
- Novel Device and Instrumentation Development (subtopics n-o)
- High-Power Targets and Target-Related Technologies for LBNF/DUNE (subtopics p-u)

Grant applications are sought only in the following subtopics:

a. Beamline Components for Emittance Re-partitioning

Grant applications are sought to develop phase space manipulation and associated beamline components capable of repartitioning the beam emittances between the three degrees of freedom.

Questions – Contact: John Boger, john.boger@science.doe.gov

b. Methods for Generating High Transformer Ratios in Structure-Based Wakefield Acceleration

Development of advanced beam phase space manipulation techniques and the associated wakefield structures to produce high transformer ratios (TR) are critical to the collinear wakefield concept.

Grant applications are sought that develop (1) a low-cost robust longitudinal bunch shaper to provide electron bunches capable of exciting wakefields with TR>2, and/or (2) wakefield structures to efficiently exploit shaped bunches to produce high gradient acceleration.

Questions – Contact: John Boger, john.boger@science.doe.gov

c. Beam Optics for Laser-Driven Ion Accelerators

Direct laser acceleration of protons or ions requires ultrahigh laser intensities focused on thin target foils or supersonic gas jets. Compact ion sources based on this technique hold promise for a variety of applications. Monoenergetic proton or ion energies in the range of 2–50 MeV/u with an energy spread no more than 10% are of interest. Some of these applications require methods that focus, collimate, control the energy spectrum, and select a single ion species for subsequent acceleration. Grant applications are sought to develop ion collection, selection, transport and focusing optics that efficiently select one ion species, reduce the energy spread to 10%, and focus the ion beam to a spot of a few mm in size no more than 2 meters downstream from the laser target.

Questions – Contact: John Boger, john.boger@science.doe.gov

d. Supersonic Gas Jets with Programmable Density Profiles

Grant applications are sought to develop high density (range of 10E19-10E20 /cc), high repetition rate (≥10 Hz) pulsed gas jets with precisely shaped density profiles. Efficient acceleration of mono-energetic proton beams can be achieved with a CO2 gas laser focused on a pulsed supersonic gas jet with tailored longitudinal density profile. The main goal of a shaped density gas jet is to prevent the appearance of electrostatic fields at the rear surface of the target; these fields are responsible for energy broadening of the ion beam. The most effective way to reduce those fields is to introduce an exponential drop in density over a scale length of a few hundred microns. The density profile at the front of the gas jet should follow a linear increase in density over a distance of 100 to 150 microns. In order to accelerate protons to high energies, the gas jet peak density should be controlled from about the critical density of the laser driver used, which is 10E19/cc for CO2 lasers, to as much as ten times the critical density. Additionally, such gas jets may have potential applications to H- stripping injection in circular accelerators.

Questions – Contact: John Boger, john.boger@science.doe.gov

e. Plasma Targets with Programmable Density Profiles

Grant applications are sought to develop precisely shaped plasma target density profiles for emittance control and density tailoring for injection and guidance into laser plasma accelerators. Approaches could include the use of pulsed cluster gas jets, where high local density within clusters greatly enhances coupling of laser energy to both ions and electrons [1]. This enhanced coupling, along with the ballistic behavior of these clusters around flow obstacles, can enable low energy table top laser systems to perform plasma shaping. Hydrogen clusters are important to enable use of the resulting plasma for high intensity laser targets, and high repetition rate (≥10 Hz) is needed. A well-characterized source that produces clustered gases of carefully controlled size, composition, and high mean density is important to density tailoring. Other approaches that employ nearly hollow channels are also of interest.

Questions – Contact: John Boger, john.boger@science.doe.gov

f. Novel High Gradient Accelerating Techniques

Grant applications are sought to develop new or improved accelerator designs that can provide very high gradient (>200 MV/m for electrons or >15 MV/m for protons) acceleration of intense bunches of particles, or efficient acceleration of intense (>50 mA) low energy (of order <20 MeV) proton beams. For all proposed concepts, stageability, beam stability, manufacturability, and high-wall-plug-to-beam power efficiency must be considered.

Questions – Contact: John Boger, john.boger@science.doe.gov

g. Novel Beam Optics for High-Energy, High-Intensity Proton Accelerators

Grant applications are sought for the development of new ideas in beam optics and lattice design for the High-Luminosity LHC (HL-LHC), for the Proton Improvement Plan (PIP-II) at Fermilab, and for other proposed proton facilities that will advance the Energy Frontier or the Intensity Frontier. The drive towards higher luminosity calls for flat proton beams with ultra-low emittance in one transverse plane; however, space charge tune shifts in the injector chain can become unacceptably large for present lattice designs. Fundamentally different approaches to lattice design may enable order-of-magnitude lower emittances, with corresponding increases in luminosity. For Intensity Frontier rings, one of the intensity-limiting effects is excitation of head-tail space-charge modes, which are still not understood in sufficient detail. Computational studies of such modes in realistic lattices are required to better understand the importance of such modes and to develop ways of suppressing them.

Questions – Contact: John Boger, john.boger@science.doe.gov

h. Advanced Concepts and Modeling for PIP-II

Grant applications are sought to develop new or improved accelerator designs and supporting modeling that can provide efficient acceleration of intense particle beams in either linacs or synchrotrons with beam losses of less than 1 W/m. Topics of interest include: (1) Linac configurations, either pulsed or CW, capable of delivering >1 MW beams at energies between 1-10 GeV; (2) Halo formation in pulsed or CW linacs; (3) Concepts for high-intensity, rapid cycling synchrotrons; (4) Space-charge mitigation techniques; and (5) New methods for multi-turn H– injection, including laser stripping techniques.

Questions – Contact: John Boger, john.boger@science.doe.gov

i. Improved Accelerator Modeling Simulation Codes

Grant applications are sought to develop new or improved computational tools for the design, study, or operation of charged-particle-beam optical systems, accelerator systems, or accelerator components. These tools should incorporate innovative, user-friendly interfaces, with emphasis on graphical user interfaces and windows, and tools to translate between standard formats of accelerator lattice description. Grant applications also are sought for the upgrade of existing codes

to incorporate these interfaces (provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate).

Questions – Contact: John Boger, john.boger@science.doe.gov

j. Improved Integration of Accelerator Codes

Grant applications are sought to enhance simulations of accelerator systems by (1) developing user-friendly tools that enable software integration of existing codes for different components, such as preprocessors and postprocessors, or (2) for fitting different application codes into an overall framework.

Questions – Contact: John Boger, john.boger@science.doe.gov

k. Accurate Modeling and Prediction of High Gradient Breakdown Physics

Grant applications are sought to develop simulation tools for modeling high-gradient structures that predict such experimental phenomena as the onset of breakdown, post breakdown phenomena, and the damage threshold. Specific areas of interest include, although not limited to, the modeling of: (1) Surface emission, (2) Material heating due to electron and ion bombardment, (3) Multipacting, and (4) Ionization of atomic and molecular species. Approaches that include an ability to import/export CAD descriptions, a friendly graphical user interface, and good data visualization are sought.

Questions – Contact: John Boger, john.boger@science.doe.gov

l. High Current Electron Sources

Grant applications are sought for robust ampere-class electron sources for very high power beam applications. Such electron sources must be capable of producing average currents in excess of 1 ampere with transverse emittances compatible with very-low-loss capture in a microwave accelerator. Cathodes must operate continuously with minimal downtime, and be field-replaceable without significant equipment, time, or expertise. Cathodes suitable for use in either room-temperature or cryogenic conditions are sought.

Questions – Contact: John Boger, john.boger@science.doe.gov

m. Particle Beam Sources for PIP-II

Grant applications are sought for the design and demonstration of low emittance H–sources capable of continuous operation at up to 15 mA with a long lifetime. Long lifetime means greater than minimally one month, with concurrent high reliability in operations. Of particular interest are sources operating at ~30 keV.

Questions – Contact: John Boger, john.boger@science.doe.gov

n. Novel Device and Instrumentation Development for PIP-II

Grant applications are sought for beam deflecting devices that can be used to remove or deflect proton or ion bunches for the purpose of forming variable bunch patterns in high intensity proton accelerators (see also "Deflecting Cavities" in next topic).

Specific areas of interest include:
Deflecting structures capable of removing individual bunches within a beam from a ~2 MeV CW source, and with a 162.5 MHz bunch structure; specifically with capabilities of providing arbitrary chopping patterns based on selective removal of bunches spaced at 6 nsec; and

Driver concepts, either amplifier or switch based, suitable for driving such deflectors with several hundreds of volts into impedances of 50 or 200 Ohms.

Questions – Contact: John Boger, john.boger@science.doe.gov

o. Fast Beam Kicker for Wakefield Accelerator Staging Experiments:

Grant applications are sought for a fast beam kicker with 50 ns rise time and 150 kV total transverse kick.

Questions – Contact: John Boger, john.boger@science.doe.gov

p. Carbon-Based Beam Window Development

Grant applications are sought for the development of carbon-based beam windows for secondary particle production. Production of secondary particle beams require "beam windows" that isolate the target (usually in air) from the primary particle beam vacuum. Expected increases in beam power and intensity require advanced beam window solutions, such as the use of carbon-based materials. Beam windows using carbon materials (such as glassy carbon) must withstand the interaction with the high power primary beam (1 to 4 MW; at a Gaussian beam profile sigma radius down to ~1.5 mm; 10 microsec pulses; ~1 Hz), the pressure differential across the window (2 to 4 bar), and erosion caused by oxidation at elevated temperatures on the air-side of the window. The window's interaction with the beam has the potential to create thermal shock, radiation damage, and high temperatures. Cooling of the beam windows is considered critical to this development. Applications for the use of such beam windows require solutions for beam apertures ranging from 2 cm to 10 cm in diameter.

Questions – Contact: John Boger, john.boger@science.doe.gov

q. Radiation Resistant Strain/Vibration Instrumentation Development

Grant applications are sought for the development of strain/vibration instrumentation to monitor the health of a target component in a high radiation environment. Future target components for Energy and Intensity Frontier experiments are expected to withstand an accumulated dose of 10 gigagray or more during their lifetime. Strain instrumentation that can function near to this limit in the vicinity of the high power target is needed. Such instrumentation should be able to resolve strains as low as 100 nano-strain and as high as 10 milli-strain (non-concurrently). Sampling frequency is potentially as high as 4 MHz in order to capture the dynamic response of a high

intensity beam pulse (1 to 10 microsec). Exploration of the potential use of radiation hardened ultrasonic transducers and/or waveguides that meet these specifications is encouraged.

Questions – Contact: John Boger, john.boger@science.doe.gov

r. MAX Phase Material Development for High Power Targets

Particle production facilities (target facilities) require thermal shock and radiation tolerant materials for use as beam windows, targets, collimators, and/or absorbers. Expected increases in beam power and intensity require advanced material solutions, such as the use of MAX phase materials [1]. Targetry components must withstand the interaction with the high power beam (1 to 4 MW at a Gaussian beam profile sigma radius down to ~1.5 mm; 10 microsec pulses; ~1 Hz). Interaction with the beam has the potential to create thermal shock, radiation damage, and high temperatures. Applications for the use of such targetry components require solutions for beam apertures ranging from 2 cm to 10 cm in diameter and effective thicknesses of 1 mm up to 1 meter. [3]

Questions – Contact: John Boger, john.boger@science.doe.gov

s. Remote Reusable High Current Stripline Connections

Grant applications are sought for the design of remote electrical connections that can handle currents as high as 100 kA with low duty factors (0.1 – 1%). To achieve these low duty factors, these connections will be pulsed and so generate electromagnetic forces on the order of 10E8 cycles. The voltages involved are expected to range from 1 to 10 kV. Challenges to the design and fabrication of these electrical connections are (1) they must function in a high radiation environment (~ 10 gigagray), (2) are subject to the potentially corrosive effects of ozone and NOxcorrosion, (3) they need to maintain clamping pressure during pulsing.

Questions – Contact: John Boger, john.boger@science.doe.gov

t. Radiation Shielding Foam

Grant applications are sought for the development of radiation resistant foam to aid radiation shielding and sealing in radioactive environments. The foam should expand when applied, but still maintain a reasonably high density for shielding purposes (0.1 – 1.0 g/cc). Dopants to absorb neutrons would be advantageous. The foam should also produce a good air seal (like caulk) and maintain that seal during exposure. Doses of 1 megagray and above should be considered.

Questions – Contact: John Boger, john.boger@science.doe.gov

u. 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: John Boger, john.boger@science.doe.gov

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3. CAARI, August 5-10, 2012, Conference on Applications of Accelerators in Research and Industry, Fort Worth, TX, information and proceedings available at http://inspirehep.net/record/1229546?ln=en

4. Beam Instrumentation Workshop (BIW12), April 15-19, 2012, Newport News, VA, proceedings available at http://accelconf.web.cern.ch/AccelConf/BIW2012/index.htm

5. International Workshop on Neutrino Factories, Super Beams and Beta Beams, July 23-28, 2012, Williamsburg, VA, information and proceedings available at http://www.jlab.org/conferences/nufact12/

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Subtopics d and e:

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1. Henderson, S. and Waite, T., ed., 2015, Workshop on Energy and Environmental Applications of Accelerators, http://science.energy.gov/~/media/hep/pdf/accelerator-rd-stewardship/Energy_Environment_Report_Final.pdf

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25. RADIO FREQUENCY 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**

Radio frequency (RF) technology underpins all current high energy accelerators. In order to minimize future high energy accelerators' cost, DOE-HEP seeks RF sources with significantly higher efficiencies, accelerating structures and accelerating gradients. For all subtopics, applicants should understand the state-of-the-art and clearly describe in the proposal the quantitative technological advances that will result from their applications.

In cases where DOE-HEP seeks technology that is closely tied to a specific accelerator concept, that accelerator sets the specifications (and tolerances) for the technology to be proposed in the application. Applicants are strongly encouraged to review the references provided for that accelerator. DOE-HEP will decline applications to subtopics associated with an accelerator as non-responsive if they fail to follow the specifications for that accelerator.

For subtopics that are not machine-specific, applicants are strongly advised to understand the state-of-the-art and to clearly describe in the application what quantitative advances in the technology will result.

Grant applications are sought only in the following subtopics:

a. High Gradient Accelerator Research & Development

Grant applications are sought for research on very high gradient RF accelerating structures, normal or superconducting, for use in accelerators and storage rings. Electron accelerators achieving gradients appreciably greater than >100 MV/m with shunt impedances >100 MOhm/m and fabrication costs below 100k$/m are sought. Proton accelerators achieving >10 MV/m are also of interest, as are means for suppressing unwanted higher-order modes and reducing costs for both categories of accelerators.

Questions – Contact: John Boger, john.boger@science.doe.gov

b. Analysis and Mitigation of High Repetition Rate Effects in Dielectric Wakefield Accelerators

The interaction of dielectric materials with beam halo might become a significant limiting effect on the performance of dielectric wakefield devices, leading either to deflection of the beam by the static electric field generated, or to breakdown of the structure. Grant applications are sought which emphasize experimental, theoretical or computational studies of the expected charging rate and charge distribution in a thin walled dielectric device and the physics of conductivity and discharge phenomena in dielectric materials useful in accelerator applications.

Questions – Contact: John Boger, john.boger@science.doe.gov

c. Low-Temperature Bonding Techniques for Hard Copper and Hard Copper Alloys

Recent research on high-gradient normal conducting accelerator structures showed significant advantages of hard copper and hard copper alloys over annealed copper. Hard copper and hard copper alloys (e.g. copper-silver) allow these structures to run stably at higher gradients than annealed copper. However, normal manufacturing techniques, which include brazing and or diffusion bonding, anneal the copper; in the case of copper alloys there are no established bonding techniques. Grant applications are sought that can address the development of manufacturing techniques that preserve the hardness of copper or its alloys while at the same time maintain high degree of surface integrity and cleanliness for high gradient operation. Plating, low temperature brazing, and welding are examples of possible technologies for bonding structure cells; however, we would also welcome other ideas and technologies.

Questions – Contact: John Boger, john.boger@science.doe.gov

d. Radio Frequency Power Sources and Components for PIP-II

Grant applications are sought for the development of power sources for accelerating cavities operating with 1-5 mA of average beam current in linacs capable of accelerating protons and ions to several GeV. Frequencies of interest include 325 and 650 MHz. Both pulsed and continuous wave (CW) applications are of interest. Examples of systems of interest include, but are not limited to: klystrons, solid state, inductive output, and phase locking magnetron devices; their associated power supplies; and associated low level radio frequency (LLRF) control systems.

Questions – Contact: John Boger, john.boger@science.doe.gov

e. Low Cost Radio Frequency Power Sources for Accelerator Applications

Low cost, highly efficient RF power sources are needed to power accelerators. Achieving power efficiencies of 70% or better, decreasing costs below $2/peak-kilowatt for short-pulse sources, and below $3/average-kilowatt for CW sources are essential. Sources must phase lock stably (<1 degree RMS phase noise) to an external reference, and have excellent output power stability (<1% RMS output power variation). Device lifetime must exceed 10,000 operating hours. Vacuum-tube based sources should be designed to operate at <100kV beam voltage to improve reliability and reduce cost of required HV systems. Priority will be given to applications that develop RF power sources operating at frequencies that are in widespread use at the large Office of Science accelerators.

For normal conducting accelerators, microsecond-pulsed high-peak-power sources are needed that operate at L-band or higher frequencies. The peak output power of individual sources is flexible, but must be compatible with delivering ~100 MW/meter to compact accelerators. The source must support >0.1% duty factor operation.

For superconducting accelerators, both millisecond-pulsed and CW sources are needed that operate at L-band frequencies. The peak output power of individual sources is flexible, but must be compatible with delivering ~100 kW/meter to high power accelerators. If the source is not CW capable, it must support >5.0% duty factor operation.

Radiofrequency power sources of particular interest include:

- The magnetron, provided it is adapted to include control of output power by, e.g., using a grid, and stable phase control by introducing, e.g., injection locking;
- The Klystron, provided it is adapted to significantly increase power efficiency and reduce cost;
- Solid state power amplifiers, provided the high cost per watt can be significantly reduced.

Applications must clearly articulate how the proposed technology will meet all metrics listed in this section.

Questions – Contact: John Boger, john.boger@science.doe.gov

f. High Efficiency High Average Power RF Sources

Future high power accelerators will require highly efficient sources of megawatt-class radiofrequency power. Grant applications are sought to significantly improve the power efficiency of high-average-power (CW or high duty factor) radiofrequency tubes. Net tube power efficiency (including focusing magnet power) must exceed 80%, and average tube power must exceed 100 kW, with a pulse format (peak power, pulse length) that is appropriate for either normal conducting or superconducting accelerators, and an output that is stably phase locked to an external reference. The proposed device must provide an economical route to producing 1 MW or more of average power by scaling, coherent combination, or both. Priority will be given to applications that develop RF power sources operating at frequencies that are in widespread use at the large Office of Science accelerators.

Questions – Contact: Eric Colby, Eric.Colby@science.doe.gov

g. R&D for High Average Power RF Components

Future high power accelerators will require RF power transmission components capable of handling high average-power (CW or high duty factor) with low loss and high reliability. Grant applications on materials (e.g., RF window dielectrics, non-reciprocal materials for circulators, insulating gases), surface treatments (e.g. coatings and surface texturing to suppress multipactoring, field emission, and RF breakdown), processing methodology (e.g. baking, plasma processing, direct rf processing), and designs (e.g., overmoded, low surface field) are sought. The goal of this subtopic is to develop the technologies needed to manufacture RF power transmission components that can reliably support average power transmission of 100 kW – 1 MW per component. Priority will be given to applications addressing RF transmission components that tend to have the lowest power handling capabilities (e.g., RF windows, circulators) and/or those that currently use toxic or environmentally

unsustainable materials (e.g., beryllium, sulfur hexafluoride). Priority will be given to applications to develop technologies that work at RF frequencies in widespread use at the large Office of Science accelerators.

Questions – Contact: Eric Colby, Eric.Colby@science.doe.gov

h. 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: John Boger, john.boger@science.doe.gov

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6. Muon Collider Workshop 2011: Physics-Detectors-Accelerators, June 27-July 1, 2011, Telluride, CO, http://conferences.fnal.gov/muon11/

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Subtopics g and h:

1. Henderson, S. and Waite, T., 2015, Workshop on Energy and Environmental Applications of Accelerators, http://science.energy.gov/~/media/hep/pdf/accelerator-rd-stewardship/Energy_Environment_Report_Final.pdf

26. LASER TECHNOLOGY R&D FOR ACCELERATORS

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**

Lasers are used or proposed for use in many areas of accelerator applications: as drivers for novel accelerator concepts for future colliders; in the generation, manipulation, and x-ray seeding of electron beams; in the generation of electromagnetic radiation ranging from THz to gamma rays; and in the

generation of neutron, proton, and light ion beams. In many cases ultrafast lasers with pulse lengths well below a picosecond are required, with excellent stability, reliability, and beam quality. With applications demanding ever higher fluxes of particles and radiation, the driving laser technology must also increase in repetition rate—and hence average power—to meet the demand. Please note that proposals submitted in this topic should clearly articulate the relevance of the proposed R&D to HEP's mission.

This topic area is aimed at developing technologies for ultrafast lasers capable of high average power (kilowatt-class) operating at the high electrical-to-optical efficiency (>20%) needed for advanced accelerator applications. Accelerator applications call for lasers with one of four basic specifications:

	Type I	**Type II**	**Type III**	**Type IV**
Wavelength (micron)	1.5-2.0	0.8-2.0	2.0-5.0	2.0-10.0
Pulse Energy	3 microJ	3 J	0.03–1 J	300 J
Pulse Length	300 fs	30–100 fs	50 fs	100–500 fs
Repetition Rate	1–1300 MHz	1 kHz	1 MHz	100 Hz
Average Power	Up to 3 kW	3 kW	3 kW and up	30 kW
Energy Stability	<1 %	<0.1%	<1%	<1%
Beam Quality	M2<1.1	Strehl>0.95	M2<1.1	M2<1.1
Wall-plug Efficiency	>30%	>20%	>20%	>20%
Pre-Pulse Contrast	N/A	>10-9	N/A	>10-9
CEP-capable	Required	N/A	Required	N/A
Optical Phase Noise	<5o	N/A	<5o	N/A
Wavelength Tunability Range	0.1%	0.1%	10%	0.1%

Grant applications are sought to develop lasers and laser technologies for accelerator applications only in the following specific areas:

a. Cost Reduction of Ultrafast Fiber Laser Components

Another route to achieving high peak and average power is to coherently combine the output of many (e.g. thousands of) ultrafast fiber lasers. In this case, power efficiency, beam quality, compactness, reliability, stability, and low cost of the individual lasers are each essential. Note that components and subsystems must be developed for propagating and amplifying high-quality (M2<1.2) ultrafast (<100 fs) laser pulses. Proposals that develop integrated subsystems will be given highest priority, although proposals for individual components that offer revolutionary gains in any of the performance characteristics above will also be welcomed.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

b. Ceramic-Based Optical Materials

To achieve high average power and high peak power will require new gain materials with superior damage threshold, dopant density, optical bandwidth, and thermal properties. Sintered laser gain materials for ultrafast lasers offer promise of achieving many of these characteristics. Broad bandwidth (>10%) and scalability to high peak power (>10 TW), high average power (>kW) operation is essential. In addition, the development of techniques for producing precisely controlled spatial gain profiles is strongly encouraged.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

c. Optical Coatings for Ultrafast Optics

The cost and reliability of ultrafast laser systems depend in part on the optical robustness of coated optics such as mirrors and windows. R&D proposals are sought that will lead to significant advances in low loss, low scatter, ultra-high damage threshold broad-bandwidth coatings that can sustain fluences exceeding >2 J/cm2 for 100 fs pulses. Coatings must also be stable at incident average powers exceeding 100 W, and provide high quality transmission or reflection properties over >10% bandwidth under both vacuum and in-air use. Also of interest are low-loss AR coatings with high-damage threshold that simultaneously operate at optical and THz frequencies, which can increase the efficiency and average power generated from dual frequency sources.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

d. Robust Nonlinear Optical Materials

Nonlinear optical materials for frequency conversion are key to producing a wide array of laboratory-scale sources of radiation. Materials supporting conversion of laser power to frequencies in the terahertz to EUV range (wavelength between 300 and 0.1 micron) at high conversion efficiency, high damage threshold, and at high average power (>100 W incident power, CW) are sought.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

e. Drive Lasers and for Photocathode Electron Sources

Applications are sought for developing turn-key commercial laser systems and subsystems for driving high-brightness photocathodes.

a) A self-contained turn-key laser system (including environmental enclosure and controls) producing 50 Watts of 520nm light in 1 psec pulses at 1.3 GHz with no more than 100 fsec rms timing jitter with respect to an external microwave timing reference is sought. The resultant beam must be shaped temporally and spatially, as well as have the ability for producing varying pulse trains.

b) Practical and highly efficient (>90%) methods are sought for advanced laser shaping. The technique must allow a wide range of transverse shapes (elliptical to flattop) and spot sizes (0.3-3 mm) to be projected onto a photocathode to mitigate non-linear space charge effects and concomitant emittance degradation. The shaping system must preserve the laser beam quality and be usable with high powers (10's of Watts of average laser power).

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

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 topic description above.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

REFERENCES:

1. Workshop on Laser Technology for Accelerators. January 23-25, 2013, http://science.energy.gov/~/media/hep/pdf/accelerator-rd-stewardship/Lasers_for_Accelerators_Report_Final.pdf

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27. SUPERCONDUCTOR TECHNOLOGIES FOR PARTICLE ACCELERATORS

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**

Superconducting materials are widely used in particle accelerators to create large continuous electric and magnetic fields for beam acceleration and manipulation. Advanced R&D is needed in support of this research in high-field superconductor, superconducting magnet, and superconducting RF technologies. This topic addresses only those superconducting magnet development technologies that support accelerators, storage rings, and charged particle beam transport systems, and only those superconducting wire technologies that support long strand lengths suitable for winding magnets without splices.

Grant applications are sought only in the following subtopics:

a. High-Field Superconducting Wire Technologies for Magnets

Grant applications are sought to develop new or improved superconducting wire for high field magnets that operate at 16 Tesla (T) field and higher. Proposals should address production scale (> 3 km continuous lengths) wire technologies at 16 to 25 T and demonstration scale (>1 km lengths) wire technologies at 25 to 50 T. Current densities should be at least 400 amperes per square millimeter of strand cross-section (often called the engineering current density) at the target field of operation and 4.2 K temperature. Tooling and handling requirements restrict wire cross-sectional area to the range 0.4 to 2.0 square millimeters, with transverse dimension not less than 0.25 mm. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K, so high-temperature superconducting wire technologies will be evaluated only in this temperature range. Primary conductors of interest are the HTS materials Bi2Sr2CaCu2O8 (Bi-2212), and (RE)Ba2Cu3O7 (ReBCO) that are engineered for high field magnet applications; new architectures or processing methods that significantly lower the cost of Nb3Sn wire may also be of interest. Other materials may be considered if high field performance, length, and cost equivalent to these primary materials can be demonstrated. All grant applications must result in wire technology that will be acceptable for accelerator magnets, including not only the operating conditions mentioned above, but also delivery of a sufficient amount of material (1 km minimum continuous length) for winding and testing small magnets.

New or improved wire technologies must demonstrate at least one of the following criteria in comparison to present art: (1) property improvement, such as higher current density or higher operating field; (2) improved tolerance to property degradation as a function of applied strain; (3) reduced transverse dimensions of the superconducting filaments (sometimes called the effective filament diameter), in particular to less than 30 micrometers at 1 mm wire diameter, with minimal concomitant reduction of the thermal conductivity of the stabilizer or strand critical current density; (4) innovative geometry for ReBCO materials that leads to lower magnet inductance (cables) and lower losses under changing transverse magnetic fields; (5) correction of specific processing flaws (not general improvements in processing), to achieve properties in wires of more than 1 km length that are presently restricted to wire lengths of 100 m or less; (6) significant cost reduction for equal performance in all regards, especially current density and length.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

b. Superconducting Magnet Technology

Grant applications are sought to develop: (1) very high field (20 T and above) dipole magnets; (2) designs and prototypes for HTS/LTS hybrid solenoid systems capable of achieving 30 to 40T axial fields and warm bores with a diameter ≥2 cm, which are of particular interest for final cooling of a muon beam prior to acceleration and injection into a collider storage ring, but could also have broader application; (3) alternative designs – to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets – that may be more compatible with the more fragile Nb3Sn and HTS/high-field superconductors; (4) fast cycling HTS magnets capable of operation at or above 4T/s; (5) reduction in magnetization induced harmonics in HTS magnets; (6) improved magnet designs and industrial fabrication methods for magnets, such as welding and forming, that lead to lower costs; (7) quench protection in HTS magnets and HTS/LTS hybrid magnets.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

c. Superconducting RF Materials & Cavities

Materials and Fabrication Technologies for SRF Cavities – Material properties, surface features, processing procedures, and cavity geometry can have significant impact on the performance of superconducting radio-frequency (SRF) accelerator cavities. Grant applications are sought to develop (1) new raw materials streams, such as those utilizing large-grain Nb ingot slices; (2) new or improved SRF cavity fabrication techniques, such as seamless and weld-free approaches; (3) SRF cavity fabrication techniques that reduce use of expensive metals such as niobium while achieving equivalent performance as bulk niobium cavities; (4) new or improved bulk processing technologies, such as mechanical or plasma polishing; (5) new or improved final surface preparation and protection technologies; (6) techniques to coat copper (or other) cavity substrates with SC thin-film materials with RF properties that meet or exceed those of bulk Nb and/or enable operation at 4 K or above.

SRF Cavities – Grant applications are sought for the development of superconducting radiofrequency cavities for acceleration of proton and ion beams, with relativistic betas ranging from 0.1 to 1.0. Frequencies of current interest include 325, 650, 1300 MHz and S-band to 4 GHz. Continuous wave (CW) cavities are of the greater interest, although pulsed cavities could also be supported. Accelerating gradients above 15 MV/m, at Q0 in excess of 2 × 1010 (CW), and above 25

MV/m at Q0 in excess of 1 × 1010 (pulsed) are desirable. Topics of interest include: (1) cavity designs; (2) cavity fabrication alternatives to electron beam welding, including for example hydroforming and automatic TIG or laser welding of cavity end groups; (3) other cavity and cryomodule cost reduction methods; (4) cw power couplers at >50kW; (5) fast tuners for microphonics control; (6) higher order mode suppressors, including extraction of HOM power via the main power coupler and with photonic band gap cavities; (7) ecologically friendly or alternative cavity surface processing methods; (8) alternatives to high pressure rinsing that would allow in-situ cleaning of cavities to control field emission; (9) high resolution tomographic x-rays of electron beam welds in cavities; (10) novel SRF cryomodule design including demonstration of conduction cooled SRF cavities.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

d. Cryogenic and Refrigeration Technology Systems

Many new accelerators are based on cold (superconducting) technology requiring large cryogenic systems. Grant applications are sought for research and development leading to the design and fabrication of improved cryomodules for superconducting cavity strings. Each cryomodule typically contains four to eight cavities in helium vessels and includes couplers, tuners, quadrupoles, 2K helium distribution system, and instrumentation to measure temperatures and pressures in the cryomodule during cool down and operation. Improvements in cryomodule components, cryomodule design and fabrication techniques which result in lower costs, improved control of cavity alignment, better understanding of cavity temperatures, and lower heat leaks are of particular interest. Other areas of interest include optimized methods for current leads for magnet operation at 2K where the helium pressures are sub atmospheric and use of cryocoolers to cool SRF cavities.

Grant applications also are sought to increase the technical refrigeration efficiency – from 20% Carnot to 30% Carnot – for large systems (e.g. 10 kW at 2K), while maintaining higher efficiency over a capacity turndown of up to 50%. This might be done, for example, by reducing the number of compression stages or by improving the efficiency of stages. Grant applications also are sought to develop improved and highly efficient liquid helium distribution systems.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

e. Ancillary Technologies for Superconductors

Grant applications are sought to develop innovative cable designs and wire processing technologies. Approaches of interest include methods to use stranded conductors with high aspect ratio to make efficient magnet cables, methods to adapt tape geometries to particle accelerator applications, and technologies to increase wire piece length and billet mass.

Grant applications also are sought for development of thermally efficient conduction cooled power leads for superconducting magnets through the use of good thermal intercepts which also electrically isolate. This would benefit all applications of superconducting magnets and PIP-II (Replacement of the Fermilab Proton Source and Linac).

Grant applications also are sought for innovative electrical insulating materials with reduced thickness to increase block current density in a coil while maintaining or increasing dielectric breakdown strength. Insulating systems must be compatible with the targeted superconductor and magnet processing cycle, (e.g. high temperature reactions in the 750-900 ºC range in the case of Nb3Sn or BSCCO), be capable of supporting high mechanical loads at both room and cryogenic temperatures, have a high coefficient of thermal conductivity, be resistant to radiation damage, and exhibit low creep and low out-gassing rates when irradiated.

Grant applications also are sought for superconducting materials used as shields for high magnetic fields (~1T and more) in places where space is at a premium. A typical example is the Muon g-2 Inflector magnet, which is the last magnet in the muon injection system in the ring. Such a shield requires a superconducting material, e.g. NbTi sheets, with dimensions of 2 m x 0.5 m fabricated in a multilayer composite with total thickness in the range of 0.5 mm - 1 mm. Other superconducting materials might also be considered including Nb3Sn and MgB2.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

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 topic description above.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

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2. Scanlan, R., et al., 2004, Superconducting Materials for Large Scale Applications, Proceedings of the IEEE, vol. 92, issue 10, pp. 1639-1654, available at http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1335554&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F5%2F29467%2F01335554

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28. HIGH-SPEED ELECTRONIC INSTRUMENTATION FOR DATA ACQUISITION AND PROCESSING

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 Energy Physics experiments require advanced electronics and systems for the recording, processing, storage, distribution, and analysis of experimental data. High-priority future experiments in the DOE Office of High Energy Physics portfolio need advances that can benefit from small business contributions. These experiments include those planned for the High Luminosity (HL) Upgrade of the Large Hadron Collider (www.cern.ch), Neutrino Experiments including those sited deep underground (e.g., www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand cosmic acceleration, including Cosmic Microwave Background experiments. We seek small business industrial partners to advance the state of the art and/or increase cost effectiveness of instrumentation needed for the above experiments. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. R&D seeking new technology will typically be in progress at DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific technology areas, the scientists involved are the best source of detailed information about requirements and relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists in order to develop germane proposals. Clear and specific relevance to high energy physics programmatic needs is required, and supporting letters from lab and university scientists are an excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov.

Grant applications are sought in the following subtopics:

a. Special Purpose Integrated Circuits for HL-LHC Detectors

Particle physics detectors make heavy use of application specific integrated circuits (ASICs), which are designed by engineers at national laboratories and universities and fabricated through commercial foundries. ASICs must meet special requirements that typically preclude the use of commercial off-the-shelf components, such as high total dose radiation tolerance. We are interested in IP blocks and design methodologies that are compatible with radiation hardness and other special requirements. Functionalities needed include low-voltage high-speed I/O, digital signal processors, data compression, error correction, design for test circuits, etc. Circuits using 130nm and 65nm

CMOS nodes are of interest for HL-LHC upgrades. Radiation hard versions of existing commercial IC's are also of interest (see subtopic d). Low-cost prototyping and ways to reduce mask costs are also of interest.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

b. Special Purpose Integrated circuits for DUNE

For large cryogenic detectors such as DUNE it will be desirable to place electronics within the cryogenic volume. This will make access impossible throughout the useful lifetime of the detector of about 20 years. While the analog electronics benefit from a fundamental reduction in intrinsic noise due to the low temperature, CMOS digital logic may have a shortened lifetime due to hot electron effects that arise due to the increased carrier velocities. Manufacturers typically characterize the operation of their parts only to -40C. It is therefore unlikely that off-the-shelf parts will be used at noble liquid temperatures due to the lifetime uncertainty even if they are found to work. Instead there is a strong interest in developing ASICs in commercial processes. Complex digital functions will require digital logic synthesis. Digital libraries must therefore be characterized and possibly modified for cryogenic operation. Partnerships between lab/university researchers and small business could probably best accomplish this goal. Development and testing digital library timing files for sub-micron integrated circuit processes at temperatures below -100C is of interest. Design and characterization of digital library parts in a 65nm CMOS process for long lifetime at temperatures below -100C are of interest.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

c. Fabrication of Custom Real Time Massively Parallel Trigger Processors for HL-LHC

Many next-generation scientific experiments will be characterized by huge quantities of data, taken at high rates, from which scientists will have to unravel the underlying physical processes. In most cases, large backgrounds will overwhelm the physics signal of interest. Since the quantity of data that can be stored for later analysis is limited, real-time event selection is imperative to retain interesting events while rejecting background signals.

For example, the silicon-based tracking trigger system for the high luminosity LHC will have to process in real time about 100 Tbps data with few micro-seconds processing latency, to analyze billions of proton-proton collisions every second. This requires extremely high bandwidth data communication as well as massive pattern recognition power. Current technology cannot be scaled in a simple manner to accommodate trigger demands at high-luminosity LHC. Significant improvements or breakthroughs will be needed. Proposals are sought for new technology to significantly improve real time high speed low latency data communication, as well as state of the art fast pattern recognition capability. Examples include (but are not limited to) board or module designs with multi Tbps interface capability, PCB design technologies that are compatible with next-generation 100G full-mesh backplane or beyond, technology to integrate modern FPGAs directly with custom ASIC chips dedicated for fast pattern recognition, and stacked content addressable memory based pattern recognition associative memory using advanced 3D IC technology.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

d. Radiation-hard High Bandwidth Data Transmission for HL-LHC Detectors

Detector data volumes at the High Luminosity LHC will be nearly 100 times more than today. Single subdetectors will have to transmit 10's to 100's of Tb/s. While commercial off the shelf data transmission solutions will deliver the needed performance in the near future, these products cannot be used in HL-LHC for two main reasons: they will not function in a high radiation environment, and they are in general too massive to be placed inside detectors, where added mass degrades the measurements being made. Two main industrial developments are therefore of interest: very low mass, high bandwidth electrical cables, and radiation hard optical transceivers.

Electrical cables may be twisted pair, twinax, etc., with as low as possible mass (and therefore small size) while compatible with multi-Gbps per lane transmission over distances up to 6m. Cable fabrication using aluminum, copper clad aluminum, or non-metallic conductors (such as CNT thread), is of interest. Many dielectrics are not radiation hard, so fabrication with non-standard dielectrics is important.

Optical transceivers in the range 40 to 100 Gbps will be needed. Many off the shelf commercial products meet or exceed the required bandwidth, but contain circuits that fail when exposed to ionizing radiation. Radiation hardened versions of commercial transceivers (or equivalent) are therefore of interest, where radiation hardness is achieved without adding mass or increasing size, for example by design changes to the integrated circuits used.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

e. High Density Chip Interconnect Technology for HL-LHC

The demands on silicon particle tracking detectors in terms of pixel size, mass budget, data rate, and front-end processing are increasing. Grant applications are sought for the development of new technologies for reducing cost while increasing the density of interconnection of pixelated sensors to readout electronics by enhancing or replacing solder bump-based technologies. Development of cost-effective technologies to connect arrays of thinned integrated circuits (< 50 microns, with areas of ~2x2 cm^2) to high-resistivity silicon sensors with interconnect pitch of 50 microns or less are of interest. Technologies are sought that can minimize dead regions at device edges and/or enable wafer-to-wafer interconnection, by utilizing 3D integration with through-silicon vias or other methods.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. Radiation Hard CMOS Sensors for Future Particle Collider Detectors

Silicon detectors for high energy physics are currently based on hybrid technology, with separately fabricated diode strip or pixel sensors and CMOS readout chips. As larger area detectors are required for tracking and also for new applications such as high granularity calorimetry, lower manufacturing cost is needed. Monolithic Active Pixel Sensors (MAPS) in CMOS technology have the potential for low cost, of order $0.1M or less per square meter of instrumented area. For use in high energy physics, detectors must withstand both ionizing and displacement damage radiation, and they must have fast signal collection and fast readout. Radiation tolerance in the range 10 to 1000 Mrad and 1E14 to 2E16 neutron equivalent fluence is of interest. Charge collection time of 20ns or less is of interest. Fabrication of CMOS sensors on high resistivity silicon wafers is of interest to meet

these goals. MAPS devices with fast readout (frame rate of 1MHz or higher for 0.1% occupancy frames), as well as passive diode sensors fabricated on 8" or 12" wafers in a CMOS line are of interest. Reticle stitching technology may allow fabrication of large format sensors with low cost.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

g. Large-area Silicon-based Sensors for Precise Tracking and Calorimetry

Next generation collider experiments will require finely segmented silicon-based tracking and calorimetry detectors which may cover 100's of square meters. These are typically based on wafer-scale high resistivity silicon diode arrays with 100-300 micron thick fully depleted active regions. Arrays based on tiled CMOS sensors with thin active regions are also candidates. Grant applications are sought for the development of silicon diode-based sensors utilizing lower cost per unit area fabrication technologies. These may include sensors based on large (8" or beyond) wafer diameter, simplified processing, or tiling or stitching technologies. Desired properties include high yield for wafer scale sensors, radiation hardness, thinning to the hundred micron-level with backside ohmic contacts, ten micron-level resolution capability for tracking detectors, and low cost in large volumes.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

h. Radiation Hard, Low Mass IC Power and High Voltage Delivery Circuits for HL-LHC

Future collider experiments will require high efficiency, low mass, power converters that are radiation hard, have low radiated noise, and can operate in a magnetic field. Novel circuits or systems are sought that utilize high frequency DC-DC converters, GaN transistors, compact coil designs, serial powering schemes or other low loss power transmission designs that can deliver significant power to modern ICs that operate at approximately one volt supply levels. Conversion ratios of 4 or higher are needed in order to sufficiently reduce the mass of power delivery wiring needed. In addition, static on/off switching of low current, high voltage (1KV) is of interest.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

i. Frequency Multiplexed DAQ Systems Motivated by CMB Detectors.

Future CMB experiments will have large focal plane arrays with ~100k superconducting detector elements for optical, near-IR, millimeter and microwave astronomical surveys. Grant applications are sought for the development of data acquisition systems for these arrays and for detectors needing similar systems. Areas of development include low-noise cryogenic amplifiers (HEMT, SQUID, Parametric, etc.), high-density cryogenic interconnects, high-frequency superconducting flex circuits, and specialized electronics for processing large numbers of frequency domain multiplexed RF signals.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

j. 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: Helmut Marsiske, helmut.marsiske@science.doe.gov

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4. 13th Pisa Meeting on Advanced Detectors, May 24-30, 2015, La Biodola, Isola d'Elba, Italy. http://www.pi.infn.it/pm/2015/

5. International Conference on Technology and Instrumentation in Particle Physics 2014 (TIPP2014), June 2-6, 2014, Amsterdam, The Netherlands, http://www.tipp2014.nl/index.html

6. 19th Real-Time Conference, May 26-30, 2014, Nara, Japan, http://rt2014.rcnp.osaka-u.ac.jp/

7. 13th Vienna Conference on Instrumentation, February 11-15, 2013, Vienna, Austria, http://vci.hephy.at

29. HIGH ENERGY PHYSICS DETECTORS AND INSTRUMENTATION

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 Energy Physics experiments require specialized detectors for particle and radiation detection. High-priority future experiments in the DOE Office of High Energy Physics portfolio need advances that can benefit from small business contributions. These experiments include those planned for the High Luminosity (HL) Upgrade of the Large Hadron Collider (www.cern.ch), Neutrino Experiments including those sited deep underground (e.g., www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand cosmic acceleration, including Cosmic Microwave Background experiments.

We seek small business industrial partners to advance the state of the art and/or increase cost effectiveness of detectors needed for the above experiments. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. Improvements in the sensitivity, robustness, and cost effectiveness are sought. R&D towards these ends will typically be in progress at DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific detector areas, the scientists involved are the best source of detailed information about requirements and relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists in order to develop germane proposals. Clear and specific relevance to high energy physics programmatic needs is required, and supporting letters from lab and university scientists are an

excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov.

Grant applications are sought in the following subtopics:

a. Lower Cost, Higher Performance Visible/UV Photon Detection

Detectors for particle physics need to cover large areas with highly sensitive photodetectors. Experiments require combinations of the following properties:

- Large photosensitive area, compatible with cryogenic and/or high pressure operation, and built with low-radioactivity materials for neutrino and dark matter detectors.
- Fast response, radiation hardness, magnetic field compatibility, and high quantum efficiency for LHC and intensity frontier experiments
- Low cost and high reliability

Technologies using modern manufacturing processes and low cost materials are of interest. These include use of semiconductor-based avalanche photodiodes (APD) and Geiger mode APD arrays, SiPM arrays, large area microchannel plate-based systems, new photocathode materials, and high volume manufacturing of large-area, ultra clean, sealed vacuum assemblies.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

b. Ultra-low Background Detectors and Materials

Experiments searching for extremely rare events such as nuclear recoils from WIMP dark matter particles or neutrinoless double beta decays require that the detector elements and the surrounding support materials exhibit extremely low levels of radioactivity. The presence of even trace amounts of radioactivity in or near a detector induces unwanted effects. New instruments and techniques are needed and may include: 1) Instruments to measure ultra-low-backgrounds of gamma, neutron and alpha particles; 2) Improvements in the ability to measure and control radon or surface contamination; 3) Development of ultra-radio-pure materials for use in detectors; and 4) Manufacturing methods and characterization of ultra-low- background materials.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

c. Picosecond Timing Particle Detectors

Charged particle detector systems with fast response, below 100ps time resolution, and low cost to cover large areas are of interest. Detectors must be capable of fine segmentation at the sub-mm level and tolerate high particle rate, of order MHz/sq.cm. Detectors capable of precise time measurement for the passage of single charged particles are of interest for future collider experiments.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

d. Advanced Composite Materials

The High Luminosity LHC detectors will require ultimate performance detector mechanical support and cooling, that holds detector elements with micron precision and stability, and yet adds as close to zero mass as possible. Developments in this area could also be applicable to other high-priority programs. Of interest are: novel low-mass materials with high thermal conductivity and stiffness, very high thermal conductivity (<4 Wm/K) radiation tolerant adhesives, low mass composite materials with good electrical properties for shielding or data transmission, radiation hard low loss dielectric materials, improvements to manufacturing processes to take advantage of the new materials.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

e. Cryogenic Bolometer Array Technologies

Future Cosmic Microwave Background experiments will require arrays of order 100,000 bolometers. Several fabrication processes are needed to enable such large scale detectors, and can also be applicable to other experiments.

- Sub-kelvin (10-70mK base) cryogenic systems suited for operation of large arrays for superconducting bolometers. New systems would have large operational cryogenic volumes, cryogen-free operation, high cooling power with multiple thermal intercepts, closed-cycle and continuous-cycle operations.
- Mechanical systems and bearings for operation in vacuum at cryogenic temperature.
- Wafer processing combining niobium metal and MEMS.
- Anti-reflective coating technology that allows conformal application with excellent uniformity.
- Production of large area lenslet arrays for IR light, using hard materials, such as sapphire, alumina, and silicon (5mm size 3D features on wafer scale).
- Fabrication of miniature, ultra-low loss, superconducting capacitor and inductor arrays.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. Scintillating Materials And Wavelength Shifters

High Energy Physics utilizes scintillating materials for large calorimeters in colliding beam and intensity frontier experiments as well as the active medium in some neutrino and dark matter detectors. Development of radiation-hard scintillators and wavelength shifting materials is of particular interest to the colliding beam community. Development of better wavelength shifting materials is of interest for liquid noble gas detectors for neutrinos and dark matter. Brighter, faster radiation hardened crystals with high density are of interest for intensity frontier experiments as well as colliding beam experiments.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

g. Integral Field Spectrographs for Sky Surveys

The HEP community has identified integral field spectroscopy as an area that could dramatically leverage investments in current and future sky surveys for the study of Dark Energy. Grant applications are sought for the development of instrumentation that would increase the number of

spectroscopic channels or the light collection efficiency for future instruments. Examples include, but are not limited to, novel multi-fiber positioning systems, spectrographs, optical filters and sensors.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

h. Technology for Large Cryogenic Detectors

Liquid noble gas detectors are in use and under development for dark matter and neutrino experiments and in the latter case on a very large scale - as large as 10 kton modules of liquid argon for the DUNE experiment. These large scale cryogenic detectors require significant technological advances.

Electrical feedthroughs through cryostat walls are needed for low voltage power, high speed (~1Gb/s) signals, monitoring and control signals, and High Voltage (100 - 200kV) DC bias. A typical case might require 1000 total wires penetrating the cryostat wall, with HV connections having each a dedicated feedthrough. These penetrations need to be area-efficient, minimize cold leaks, and control contamination. Feedthroughs are generally warm (i.e., the interior cable enters the cryostat in the gas rather than liquid phase) but in some instances cold feedthroughs (i.e., entry directly into the liquid) are required.

Purification materials and filtration systems (e.g., submersible low-noise pump) for efficient operation of high purity multi-kiloton cryogenic noble liquid systems are needed.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

i. 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: Helmut Marsiske, helmut.marsiske@science.doe.gov

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15. International Conference on Technology and Instrumentation in Particle Physics 2014 (TIPP2014), Amsterdam, June 2-6, 2014, The Netherlands, http://www.tipp2014.nl/index.html

16. IEEE Symposium on Radiation Measurements and Applications (SORMA WEST2012). May 14-17, 2012, Oakland, CA, http://sormawest.org/

17. 13th Vienna Conference on Instrumentation, February 11-15, 2013, Vienna, Austria, http://vci.hephy.at

PROGRAM AREA OVERVIEW: OFFICE OF NUCLEAR ENERGY

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

The primary mission of the Office of Nuclear Energy (NE) is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, nonproliferation, and security barriers through research, development, and demonstration as appropriate [2].

For additional information regarding the Office of Nuclear Energy priorities see, http://energy.gov/ne/office-nuclear-energy

30. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

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**

New methods and technologies are needed to address key challenges affecting the future deployment of nuclear energy and to preserve U.S. leadership in nuclear science and engineering, while reducing the risk of nuclear proliferation. This topic addresses several key areas that support the development of crosscutting and specific reactor and fuel cycle technologies.

Grant applications are sought in the following subtopics:

a. Advanced Sensors and Instrumentation (Crosscutting Research)

Improvements and advances are needed in the technical area of Advanced Sensors and Instrumentation for crosscutting technologies for innovative sensors and measurement technologies to: characterize parameters that directly support existing power reactors, materials test reactors, and transient test reactors; enable the development of advanced power reactor designs; and facilitate development and implementation of advanced fuel cycle technologies.

Applications are sought for innovative robust methods for transmitting signals and data in a nuclear environment. The selected technology should be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting.

Research objectives:

- develop and demonstrate the ability to transmit greater amounts of data and other signals through physical boundaries in nuclear facilities;
- address new communication demands needed for advanced measurement and control technologies including protection of data;

- take into consideration the environment and the conditions under regular operation and/or accident scenario;
- test and validate prototype through demonstration in appropriate representative environment.

Applications must address each of the above objectives to be considered responsive to this subtopic. If one of the objectives is not applicable, an explanation must be provided.

Grant applications that address the following areas are NOT of interest for this subtopic and will be considered nonresponsive: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; U. S. Nuclear Regulatory Commission probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues.

Questions – Contact: Suibel Schuppner, Suibel.Schuppner@nuclear.energy.gov

b. Advanced Technologies for the Fabrication, Characterization of Nuclear Reactor Fuel

Improvements and advances are needed for the fabrication, characterization, and examination of nuclear reactor fuel. Advanced technologies are desired for light water reactor fuels and materials and for advanced reactor fuels including particulate based TRISO fuels for Advanced Gas-Cooled Reactors/NGNP applications [2, 3, 5, 6] and fuels for sodium fast reactors. Specific technologies that improve the safety, reliability, and performance in normal operation as well as in accident conditions are desired.

(1) Provide new innovative LWR fuel concepts, to include fuel and/or cladding, with a focus on improved performance (especially under accident scenarios), develop radiation-tolerant electronics for characterization instrumentation for use in hot cell fuel/cladding property measurements or characterization. Improvements to LWR fuel and cladding may include but not be limited to fabrication techniques or characterization techniques to improve the overall performance or understanding of performance of the nuclear fuel system.

(2) Develop advanced automated, accurate, continuous vs. batch mode process techniques to improve TRISO particle fuel and compacts to include: (a) improved fabrication methods for TRISO fuel kernels, particle coatings and compacts, automated fabrication and characterization methods to replace manual manufacturing techniques, and (b) advanced methods for non-destructive evaluation testing of TRISO particles and compacts for demonstration.

(3) Develop improved fabrication methods for sodium fast reactor fuels and cladding materials, especially for uranium based metallic fuel.

Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets or TRISO particles for demonstration. Actual nuclear fuel fabrication and handling applications which require use of the Nuclear Science User Facilities [4], and its hot cells and fuel fabrication laboratories, or the Oak Ridge National Laboratory Advanced Gas Reactor TRISO fuels laboratory facilities [5, 6] to demonstrate the techniques and equipment developed may be proposed. Actual nuclear fuel specimens may be considered for ATR or ORNL High Flux Isotope Reactor (HFIR) but will need to prove technical feasibility prior to their insertion

into the ATR or HFIR for irradiation testing. Access to the aforementioned facilities is not guaranteed as part of this solicitation and must be obtained independent of an SBIR/STTR award.

Grant applications that address the following areas are NOT of interest and will be considered nonresponsive: thorium based fuels, molten salt based fuels, spent fuel separations technologies used in the Fuel Cycle Research and Development Program [3] and applications that seek to develop new glove boxes or sealed enclosure designs.

Questions – Contact: Frank Goldner, Frank.Goldner@nuclear.energy.gov

c. Materials Protection Accounting and Control for Domestic Fuel Cycles

Improvements and advances are needed for the development, design and testing of new sensor materials and measurement techniques for nuclear materials control and accountability (including process monitoring) that increase accuracy, resolution, and radiation hardness, while decreasing intrusiveness on operations and the cost to manufacture. Specifically, concepts and integration of safeguards and security features into design and operation of Used Fuel storage facilities and Electrochemical Recycling facilities are being sought. Grant applications are sought for: (1) Sensors based on radiation detection; (2) Security technologies for Used Fuel dry storage that increase effectiveness and reduce manpower costs; (3) New active interrogation methods; (4) Non-radiation based sensors (stimulated Raman, laser-induced breakdown spectroscopy, fluorescence, etc.). Grant applications are also sought for the development of new methods for data validation and security, data integration, and real time analysis with defense-in-depth and knowledge development of facility state during design.

Detectors that may indicate unauthorized materials diversion can be equally useful in identifying system upsets and the need for control changes. Grant applications are sought for the development of dual-use as well as single purpose instruments and detectors. Proposed concepts used exclusively for separations process control should be submitted under subtopic g.

Grant applications that address border security or remote monitoring are NOT sought.

Questions – Contact: Daniel Vega, Daniel.Vega@nuclear.energy.gov

d. Modeling and Simulation

Computational modeling of nuclear reactors is critical for their design and operation. Nuclear engineering simulations are increasingly predictive and able to leverage high performance computing architectures. Writing software which works on leadership class facilities and is able to be used by nuclear engineers in industry presents many challenges. Grant applications are sought that:

- Can provide supporting software for nuclear engineering analyses, such as advanced meshing tools (e.g., for generation of reactor spacer grid fluid flow or structural mechanics simulations), advanced visualization tools (e.g., for projecting 1-D network flow simulation results as color maps onto 2-D graphical icons created by the user), data exchange capability between codes (e.g., for duplication of a large mesh-based data set onto an array of similar, coarser meshes), and tools for software optimization and analysis of software failure; and

- Can integrate the resultant tools and codes into a web services framework, with emphasis on the ability to connect to an open science computing framework like the open science grid.

Questions – Contact: Dan Funk, Dan.Funk@nuclear.energy.gov

e. Non-Destructive Examination (NDE) of Materials Used in Nuclear Power Plants

The development of new and innovative ideas to provide non-destructive testing techniques or monitoring technologies for long-term operation and performance of concrete and civil structures in nuclear power plants are needed. Expert panel deliberations identified long-term corrosion and creep of post-tension reinforcement tendons in containment buildings, corrosion of liners for the containment building, and corrosion of liners in spent fuel pools as possible knowledge gaps and areas in need of future development. New techniques, sensors, or monitoring capabilities would support extended service operation. Proposals targeting the identification and processional development of potential degradation modes within concrete structures (examples include alkali-silica reaction, radiation, carbonation, thermal cycling) are of high interest.

Questions – Contact: Richard Reister, Richard.Reister@nuclear.energy.gov

f. Risk Informed Safety Margin Characterization (RISMC) Software Tool Commercialization

Several U.S. National Laboratories and associated programs have successfully deployed tools developed by the Government by letting private companies manage the commercialization process (maintenance, further development, training, software support, etc.). The commercialization of software is desired to ensure that the technology is made available to the largest number of user to leverage the Government investment in the initial software development. Proposals targeting the steps needed to bring software developed through the Risk-Informed Safety Margin Characterization (RISMC) Pathway to commercial applicability are of interest. The response to this call should be the development toward code commercialization for a proposed target tool from the RISMC tool kit. The proposal should also demonstrate that the proposer has the necessary technical and business aspects to develop any proposed code modification (e.g., improved user interfaces) and to manage the code commercialization process.

Questions – Contact: Richard Reister, Richard.Reister@nuclear.energy.gov

g. Turbomachinery and Heat Exchangers for Supercritical CO2 to support Nuclear Power Systems

Supercritical CO2 (SCO2) power cycles are gaining significant interest for multiple power generation applications. These power systems are being supported by a Department of Energy crosscutting effort in the offices of Energy Efficiency and Renewable Energies (EERE), Fossil Energy (FE), and Nuclear Energy (NE). The reason supercritical SCO2 cycles have gained interest is that they are anticipated to achieve higher efficiencies than steam-based Rankine cycles at turbine inlet temperatures greater than 550°C. References show that 50% thermal-to-electric conversion efficiency can be achieved from SCO2 power cycles having turbine inlet temperatures exceeding 700°C.

Grant applications are sought for the development and design of new heat exchanger and turbomachinery for SCO2 systems that include modern manufacturing processes and operation features. Design applications are sought for advanced SCO2 Brayton Cycle heat exchangers, advanced manufacturing technologies, turbomachinery, compressors and recuperators that can be coupled near a nuclear reactor heat source and that use advanced NDE testing and PCHE in-service inspection techniques. Turbomachinery manufacturing technologies should focus on high temperature material casting methods and high pressure piping.

Questions – Contact: Brian K. Robinson, Brian.Robinson@nuclear.energy.gov

h. Advanced Methods for Manufacturing

A strong manufacturing base is essential to the success of U.S. reactor designs currently competing in global markets, but the success of the Small Modular Reactor (SMR) Initiative depends heavily on the ability of the U.S. to deliver on the SMR's expected advantages – the capability to manufacture them in a factory setting, dramatically reducing the need for costly on-site construction – thereby enabling these smaller designs to be economically competitive.

Several areas are appropriate for development by small businesses:

Advanced fabrication and manufacturing methods will require advances in welding processes and inspection methods that can maintain production speed and efficiency with the manufacturing processes. Component manufacturing technologies will be required that take full advantage of the new 3-D printing methods employed by Additive manufacturing technologies. These manufacturing methods must be capable of producing components or sub components on a limited production basis and with nuclear quality. Grant applications are sought for (1) methods to improve the process, speed, quality and cost of welding and the required in-process and post welding inspections and (2) methods and processes to fabricate components using advanced technologies like 3D printing forms of Additive manufacturing processes that can eventually produce nuclear quality components. Grant applications are also sought for methods that can improve the manufacturing processes required for nuclear components using "Just in time" manufacturing methods adapted from other industries.

Data and resource management programs are currently being considered by reactor vendors and their EPC contractors for the construction of new nuclear power plants. New nuclear plant owners will be required to manage and control the configuration of the nuclear plant through the complete nuclear plant lifetime. Significant project cost and schedule advantage can be achieved by effectively managing and maintaining configuration management (CM) of plant data beginning in the design and construction phases of the nuclear plant. Advanced methods are needed to acquire process and compare construction as-built configurations against the design. Grant applications are sought for (1) methods and technology improvements in laser, GPS and photometric systems to assure the as-built configuration matches the design, and (2) improvements in radiofrequency (RF) tags and similar devices to assure correct materials, placement, test criteria, and spare parts inventories.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

i. Material Recovery and Waste Forms for Advanced Domestic Fuel Cycles

Material recovery and waste forms play critical roles in both current and future nuclear fuel cycles. Currently, research reactor fuels are being processed in the U.S. for their stabilization while large nuclear waste treatment processing plants are in operation and are being constructed to convert cold war liquid waste into safely storable solid waste forms. An additional plant is being built to convert weapons-grade plutonium into commercial nuclear fuel. In the future, chemical processing plants may be constructed in the U.S. to recycle used nuclear fuel for improved resource utilization and reduced environmental impact. In all cases, modest improvements in chemical processing technologies can effect significant cost reductions.

In addition to the use of advanced sensors and measurement technologies for materials protection, accounting and control (as outlined in subtopic c), grants are sought for the development of related systems useful for material recovery process control. For example, detectors that may indicate unauthorized materials diversion can be equally useful in identifying system upsets and the need for control changes. Grant applications are sought for the development of dual-use as well as single purpose instruments and detectors used exclusively for process control. However, proposals that are focused on materials protection, accounting and control related applications are more appropriate for subtopic c and should be submitted there.

Most liquid high-level nuclear waste in the world is being converted to a solid form as a borosilicate glass. Such waste forms, while extremely durable, generally contain low concentrations of radioactive materials. Several approaches are under investigation to increase radioactivity concentrations and thus to decrease the total waste mass and volume for storage and disposal. Examples include the possible use of metal alloys and ceramics as advanced waste forms. Innovations are needed in waste forms chemistry and crystallinity to increase waste concentrations without the sacrifice of glass durability. Acceptability of such new waste forms as alternatives to borosilicate glass will depend upon sufficient knowledge of their degradation processes to be able to predict their performance over geologic time periods. Collaboration with national laboratory scientists involved in related studies is encouraged.

Questions – Contact: James Bresee, James.Bresee@nuclear.energy.gov

j. Cybersecurity Technologies for Protection of Nuclear Safety, Security, or Emergency Response Components and Systems

As future nuclear energy components and systems become more dependent on digital technologies, reactor operators will become more dependent on cybersecurity technologies that protect the integrity and reliability of these digital technologies. Safe, secure, reliable and cost effective products are needed to ensure operators that nuclear energy components and systems are secure from cyber-attacks or that their systems can significantly mitigate the consequences of an attack. This year proposals are requested for technologies that: 1) enhance cybersecurity awareness through novel approaches to training, education or information sharing among the community of nuclear energy stakeholders, with an emphasis on facility operators and engineers; or 2) lead to an engineering-based minimization of supply chain cyber vulnerabilities by providing a capability to reduce digital system amenities that are not needed in the unique environment of a nuclear facility.

Questions – Contact: Trevor Cook, Trevor.Cook@nuclear.energy.gov

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: Rob Versluis, Rob.Versluis@nuclear.energy.gov

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31. ADVANCED TECHNOLOGIES FOR NUCLEAR WASTE

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**

Storage of used nuclear fuel is occurring for longer periods than perhaps first intended. This being the case, it is desirable to address technical performance issues of the nuclear materials with time. Improvements and advances for the development, design, and testing of new sensors, transmitters, and measurement techniques for used nuclear fuel stored in dry storage systems for long periods of time could be beneficial. While long-term material performance studies are planned within the Used Fuel Disposition (UFD) program, there are limited opportunities to perform reliable real-time monitoring of the material condition in a sealed container or a dry storage cask. There are several monitoring devices that can be used for conventional non-destructive examinations. However, the current monitoring devices only provide limited information and the long-term reliability of the data could be questionable. Of interest to the UFD program are grant applications that propose new devices based on the long-term material behavior characteristics and/or propose new data collection and advance analyses methods that can support reliability of long-term storage options.
In addition, UFD is also interested in grant applications that address Deep Borehole and Chlorine Induced Stress Corrosion Cracking subtopics.

Grant applications are sought only in the following subtopics:

a. New Technology for Devices for Evaluating Internal Conditions of Nuclear Waste Storage Casks Nondestructively

Grant applications are sought: (1) to improve and optimize instrumentation devices using advanced techniques that relate to the fundamental properties of degrading nuclear materials, Develop a monitoring system for internal conditions in used fuel dry storage systems to identify or predict fuel cladding failure and fuel assembly structural degradation/corrosion [1, 2, 3, 4]. The attributes to be monitored might include radiation levels, temperatures, pressures, detection of certain gasses including corrosion products and radioactive decay elements, etc. (2) Develop remote and long-term monitoring of nuclear waste casks in a passive manner. The monitoring sensors might be located inside the containment canister or externally, depending on the proposed measurement technique. If internal, there shall be no penetrations through the canister; they would have to be powered without direct connections and the signals would have to be transmitted without direct connection (through thick steel shells and, possibly, concrete over-packs). The sensors and transmitters would have to sustain harsh environments (including high radiation, high temperatures, and vibration) for long periods of time (centuries) without accessibility for maintenance or calibration. The sensors and transmitters would have to sustain reorientation and vibration associated with loading and shipping the used fuel canisters from the reactors to the storage facilities. There might be several ways to solve each of these requirements. (3) Develop sensing technology to record and warn operators of events exceeding threshold of preset damage values for internals of a waste containing casks.

Questions – Contact: John Orchard, john.orchard@nuclear.energy.gov

b. Advanced Data Analyses Methodology for Nuclear Waste Containers/Casks Currently in Use

There are several monitoring devices that provide data based on interpretation of physics, chemistry, or radiological aspects of the material/structure performance. These data very often get filtered or amplified for purposes of identifying a phenomenon under consideration. However the raw data may contain additional information that could be valuable, if one is able to perform detailed or new analyses of these data. Grant applications are sought: (1) to develop methodology to extract more usable information from current monitoring devices for material degradation processes, and (2) develop and demonstrate advanced data analysis schemes with the use of multiple devices of various kinds.

Questions – Contact: Prasad Nair, prasad.nair@nuclear.energy.gov

c. Chlorine Induced Stress Corrosion Cracking

Chlorine induced stress corrosion cracking (SCC) in stainless steel (SS) dry storage canisters is an issue that the U.S. regulator, industry, and DOE is addressing. In particular, there are issues associated with conditions that initiate corrosion and resultant crack growth, as well as crack growth rate. Understanding the drivers for crack growth rate in used fuel dry storage casks is especially important as it will provide guidance on time intervals required to conduct canister inspections. Grant applications are sought to: (1). Investigate general SCC in SS canisters and weldments, and (2) investigate specific crack growth rates associated with SCC in SS canisters and weldments.

Questions – Contact: Prasad Nair, prasad.nair@nuclear.energy.gov

d. Used Fuel Disposition, Generic Repository Research and Development: Deep Boreholes

New methods and technologies could address key issues that affect the future of nuclear energy, in particular, resolution of materials disposition associated with the back-end of the nuclear fuel cycle. A further challenge is the dispositioning of defense program high-level nuclear waste products and used nuclear fuel from civilian reactors. The U.S. DOE Office of Nuclear Energy, Office of Fuel Cycle Technologies, Office of Used Nuclear Fuel Disposition R&D [1,2, 3] is currently investigating generic repository disposal systems in crystalline/granite, shale, salt, and deep borehole environments.

Proposals are sought in the following general areas:

Improvements and advances in drilling and testing technologies, and understanding of generic deep borehole environments (drilled to 5 km depth into “crystalline basement” rock) are sought; consideration should be given to examination of the feasibility of using existing drilling and testing systems and component technologies and innovative techniques to provide information to be used in the design, construction, testing, characterization, and performance assessment modeling of the deep geologic system borehole environment (chemical, hydrologic, mechanical, thermal).

Deep borehole (3-5km depth, crystalline basement rock) disposal of nuclear waste [4-19] has been considered by several nations. Research and development challenges provide opportunities for contribution to the USA’s ongoing efforts in this area including but not limited to:

- Seal integrity studies,

- Canister design and prototyping,
- Drill rig design specifications / modification for emplacement,
- Bentonite and cement degradation evaluation,
- Borehole, casing, and liner design and emplacement operations,
- Waste form degradation studies at expected environmental conditions,
- Selected radionuclide (I129, Tc99, Cl36) characterization at expected environmental conditions,
- Studies of I129 sorbent additive in seal zone: system modeling investigations to examine long-term (up to 1 million years) changes in system processes and performance for deep basement rock environments
- Age dating methods and reliability for very old groundwater (millions to billion years); including test specifications, materials, hardware requirements, test methods, distinguishing age of pore waters and fracture waters or determination of hydrologic system character and formation water residence time [19-23].

Proposals are sought to evaluate, improve, and or optimize the reliability, accuracy, and/or performance of drilling technologies and instrumentation, testing methods and applications, and modeling or analysis of deep borehole systems. Predictive and post-testing computational component, process, and system modeling and simulations are important for confidence building; it may also be advantageous to leverage high performance computing architectures and capabilities. Of particular interest are applications that propose the use of cooperative research efforts (e.g., with the national laboratories, other research institutions) in examination of the deep borehole disposal option; proposals are invited in other areas that fall within the scope of the topics described above.

Questions – Contact: Mark Tynan, mark.tynan@nuclear.energy.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: Joe Price, joe.price@nuclear.energy.gov

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32. ADVANCED SPACE POWER AND PROPULSION SYSTEMS

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 Space and Defense Power Systems, NE-75, is seeking ideas in the areas of research that can be used to advance the Office's mission to support space system research, development, demonstration, and deployment (RDD&D) activities. There are three categories of systems of interest – power conversion, fuels, and controls/components/materials.

In order to successfully develop a space system that provides reliable electric power or propulsion in space or power for extraterrestrial surface applications, such as for National Aeronautics and Space Administration science and human exploration missions, several engineering and technical challenges must be solved. NE-75 is seeking technologies for systems that meet or exceed a range of electric power outputs from 10 to 500 We or 5-50 kWe for power applications and a range of thrust outputs from 7,500 to 25,000 lb for propulsion applications. The proposed concepts/designs must be optimized for low mass, durability (both reliability and robustness) and adaptability to varying system architectures. They must also be designed for launch and operational safety. Additionally, the conservative use of fuel resources is a key factor. Further descriptions of these areas are provided below.

Grant applications are sought only in the following subtopics:

a. Advance Power Conversion Technologies for use in Potential Future Radioisotope Power Systems and Reactor Systems

The technology options that could be utilized in a 10 to 500 We or 5-50 kWe power system. System technologies should consider the following criteria: static power conversion efficiencies greater than 15%, dynamic conversion efficiencies greater that 25%, a minimum of 5 years hands free no maintenance, and a robust system design. Robustness is a system characteristic enabled by design margins that result in controlling variability such that it is tolerant to factors encountered during manufacturing, transportation, user operation, or time. Robustness in manufacturing results in a system that is tolerant to process variations. Robustness in transportation results in a system that is tolerant to handling variations. Robustness in user operation results in a system that is tolerant to environmental and control variations. Robustness in time results in a system that is tolerant to wear variations. The technology should be applicable to terrestrial or space applications.

Questions – Contact: Dirk Cairns-Gallimore, Dirk.Cairns-Gallimore@nuclear.energy.gov

b. Space Nuclear Power and Propulsion System Fuel Development

The long-lead development of fuels for space nuclear power and propulsion applications are essential for the development and demonstration of space nuclear power and propulsion systems in the next decade. In terms of fission power systems, there are several potentially viable fuel forms for space nuclear power applications. In terms of fission thermal propulsion systems, coated graphite composite fuels are the fuels of interest because of their nuclear propulsion fuel heritage, robust performance characteristics at peak operating parameters during system operation, and conservative use of highly enriched uranium. The proposed fuel forms for power or propulsion systems will be tested, optimized and certified to meet or exceed the system performance requirements, as well as fuel production and safety requirements.

Questions – Contact: Dirk Cairns-Gallimore, Dirk.Cairns-Gallimore@nuclear.energy.gov

c. Radiation Tolerant Reactor Control Systems, Components and Materials

The harsh environment of space as well the heat and radiation emanated from the reactor system could have detrimental effects to the performance of reactor control systems, components and materials. NE-75 is seeking reactor control systems, components and materials that are resistant to radiation damage, dynamic temperature changes, and varied structural loading. The proposed control systems, components and materials will be tested, optimized and certified to meet performance requirements.

Questions – Contact: Dirk Cairns-Gallimore, Dirk.Cairns-Gallimore@nuclear.energy.gov

REFERENCES:

1. United States Department of Energy, Space and Defense Power Systems, Fuel Cycle Research and Development Program. http://energy.gov/ne/nuclear-reactor-technologies/space-power-systems