U.S. Department of Energy

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program

Topics

FY 2018

Phase I

Release 2

Version 4, November 29, 2017

- Office of Defense Nuclear Nonproliferation
- Office of Electricity Delivery and Energy Reliability
- Office of Energy Efficiency and Renewable Energy
- Office of Environmental Management
- Office of Fossil Energy
- Office of Fusion Energy Sciences
- Office of High Energy Physics
- Office of Nuclear Energy

Schedule

Event	Dates
Topics Released:	Friday, November 3, 2017
Funding Opportunity Announcement Issued:	Monday, November 27, 2017
Letter of Intent Due Date:	Monday, January 8, 2018
Application Due Date:	Monday, February 26, 2018
Award Notification Date:	Monday, May 21, 2018*
Start of Grant Budget Period:	Monday, July 2, 2018

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	Nov. 2, 2017	Original
Ver. 2	Nov. 16, 2017	• Topic 10: Change to Topic description • Topic 13, subtopic a: Change of Point of Contact • Topic 24,subtopic b: Correction to subtopic description
Ver. 3	Nov. 27, 2017	• Topic 9, subtopic d: Corrected PNNL Point of Contact Phone Number and added TTO Webinar information
Ver. 4	Nov. 29, 2017	• Page 9: Correction to Technology Transfer Opportunities question for the rights to the TTO • Page 26: Change to Program Area Overview for Office of Energy Efficiency and Renewable Energy

INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2018 DOE SBIR/STTR Phase I Release 1 Funding Opportunity Announcement scheduled to be issued in on August 14, 2017. The purpose of the early release of the topics is to allow applicants an opportunity to identify technology areas of interest and to begin formulating innovative responses and partnerships. Applicants new to the DOE SBIR/STTR programs are encouraged to attend upcoming topic and Funding Opportunity Announcement webinars. Dates for these webinars are listed on our website: https://science.energy.gov/sbir/funding-opportunities/.

Topics may be modified in the future. Applicants are encouraged to check for future updates to this document, particularly when the Funding Opportunity Announcement is issued. Any changes to topics will be listed at the beginning of this document.

General introductory information about the DOE SBIR/STTR programs can be found online here: http://www.doesbirlearning.com/. Please check out the tutorials--a series of short videos designed to get you up to speed quickly.

COMMERCIALIZATION

Federal statutes governing the SBIR/STTR programs require federal agencies to evaluate the commercial potential of innovations proposed by small business applicants. To address this requirement, the DOE SBIR/STTR programs require applicants to submit commercialization plans as part of their Phase I and II applications. DOE understands that commercialization plans will evolve, sometimes significantly, during the course of the research and development, but investing time in commercialization planning demonstrates a commitment to meeting objectives of the SBIR/STTR programs. During Phase I and II awards, DOE provides small businesses with commercialization assistance through a DOE-funded contractor.

The responsibility for commercialization lies with the small business. DOE's SBIR/STTR topics are drafted by DOE program managers seeking to advance the DOE mission. Therefore, while topics may define important scientific and technical challenges, we look to our small business applicants to define how they will bring commercially viable products or services to market. In cases where applicants are able identify a viable technical solution, but unable to identify a successful commercialization strategy, we recommend that they do not submit an SBIR/STTR application.

TECHNOLOGY TRANSFER OPPORTUNITIES

Selected topic and subtopics contained in this document are designated as **Technology Transfer Opportunities** (TTOs). The questions and answers below will assist you in understanding how TTO topics and subtopics differ from our regular topics.

What is a Technology Transfer Opportunity?

A Technology Transfer Opportunity (TTO) is an opportunity to leverage technology that has been developed at a university or DOE National Laboratory. Each TTO will be described in a particular subtopic and additional information may be obtained by using the link in the subtopic to the university or National Lab that has developed the technology. Typically the technology was developed with DOE funding of either basic or applied research and is available for transfer to the private sector. The level of technology maturity will vary and applicants are encouraged to contact the appropriate university or Laboratory prior to submitting an application.

How would I draft an appropriate project description for a TTO?
For Phase I, you would write a project plan that describes the research or development that you would perform to establish the feasibility of the TTO for a commercial application. The major difference from a regular subtopic is that you will be able to leverage the prior R&D carried out by the university or National Lab and your project plan should reflect this.

Am I required to show I have a subaward with the university or National Lab that developed the TTO in my grant application?
No. Your project plan should reflect the most fruitful path forward for developing the technology. In some cases, leveraging expertise or facilities of a university or National Lab via a subaward may help to accelerate the research or development effort. In those cases, the small business may wish to negotiate with the university or National Lab to become a subawardee on the application.

Is the university or National Lab required to become a subawardee if requested by the applicant?
No. Collaborations with universities or National Labs must be negotiated between the applicant small business and the research organization. The ability of a university or National Lab to act as a subcontractor may be affected by existing or anticipated commitments of the research staff and its facilities.

Are there patents associated with the TTO?
The TTO will be associated with one or in some cases multiple patent applications or issued patents.

Will the rights to the TTO be exclusive or non-exclusive?
Each TTO will describe whether the license rights will be exclusive or non-exclusive. Licenses are typically limited to a specific field of use.

If selected for award, what rights will I receive to the technology?
Those selected for award under a TTO subtopic, will be assigned rights to perform research and development of the technology during their Phase I or Phase II grants. Please note that these are NOT commercial rights which allow you to license, manufacture, or sell, but only rights to perform research and development.
In addition, an awardee will be provided, at the start of its Phase I grant, with a no-cost, six month option to license the technology. It will be the responsibility of the small business to demonstrate adequate progress towards commercialization and negotiate an extension to the option or convert the option to a license. A copy of an option agreement template will be available at the university or National Lab which owns the TTO.

How many awards will be made to a TTO subtopic?
We anticipate making a maximum of one award per TTO subtopic. If we receive applications to a TTO that address different fields of use, it is possible that more than one award will be made per TTO.

How will applying for an SBIR or STTR grant associated with a TTO benefit me?

By leveraging prior research and patents from a National Lab you will have a significant "head start" on bringing a new technology to market. To make greatest use of this advantage it will help for you to have prior knowledge of the application or market for the TTO.

Is the review and selection process for TTO topics different from other topics?
No. Your application will undergo the same review and selection process as other applications.

DOE GRANT APPLICATION PREPARATION SUPPORT – PHASE O ASSISTANCE PROGRAM

To increase the number of high-quality SBIR/STTR Phase I applications submitted to the DOE by women-owned and minority-owned small businesses, and small businesses from DOE's underrepresented states (see eligible state list below), the DOE provides a variety of application preparation and other related services, free of charge.

Phase 0 services are offered on a first-come, first-serve basis to eligible applicants. For more information on the DOE SBIR/STTR Phase 0 Assistance Program and to determine eligibility, please visit http://www.dawnbreaker.com/doephase0/.

The following states are underrepresented in the DOE SBIR/STTR programs: AK, DC, GA, HI, IA, ID, IN, KS, LA, ME, MN, MS, MT, NC, ND, NE, NY, OK, PA, PR, RI, SC, SD, WA, WI.

PROGRAM AREA OVERVIEW: OFFICE OF DEFENSE NUCLEAR NONPROLIFERATION RESEARCH AND DEVELOPMENT

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 Defense Nuclear Nonproliferation Research and Development (DNN R&D) program directly contributes to nuclear security by developing capabilities to detect and characterize global nuclear security threats. The DNN R&D program also supports cross-cutting functions and foundational capabilities across nonproliferation, counterterrorism, and emergency response mission areas. Specifically, the DNN R&D program makes these strategic contributions through the innovation of U.S. technical capabilities to detect, identify, locate, and characterize: 1) foreign nuclear material production and weapons development activities; 2) movement and illicit diversion of special nuclear materials; and 3) global nuclear detonations.

To meet national and Departmental nuclear security requirements, DNN R&D leverages the unique facilities and scientific skills of DOE, academia, and industry to perform research and demonstrate advances in capabilities, develop prototypes, and produce sensors for integration into operational systems.

DNN R&D has two sub-Offices: Proliferation Detection and Nuclear Detonation Detection.

The Office of Proliferation Detection (PD) develops advanced technical capabilities in support of the following three broad U.S. national nuclear security and nonproliferation objectives: (1) detect, characterize, and monitor foreign production and movement of special nuclear materials; (2) detect, characterize, and monitor foreign development of nuclear weapons and to support the nuclear counterterrorism and incident response mission; and (3) provide enabling capabilities for multi-use applications across the NNSA and interagency community.

The Office of Nuclear Detonation Detection (NDD) performs the following three national nuclear security roles: (1) produce, deliver and integrate the nation's space-based operational sensors that globally detect and report surface, atmospheric, or space nuclear detonations; (2) advance seismic and radionuclide detection and monitoring capabilities that enable operation of the nation's ground-based nuclear detonation detection networks; and (3) advance analytic nuclear forensics capabilities related to nuclear detonations.

1. NEAR FIELD DETECTION TECHNOLOGIES

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

The Office of Proliferation Detection (PD) is interested in developing new and novel technologies and concepts for near field detection systems and instrumentation. PD is seeking improved equipment for response units to find and locate devices or components which emit radiation in order to prevent adversarial activities.

Continued technological advances in materials and electronic instrumentation can incrementally improve the detection range and time.

a. Radiation Detection Material Advancement

Ceramic and composite material research is needed. Improvements for lower cost, larger volume, and better energy resolution than sodium iodide based systems are essential. Emphasis is placed on the eventual creation of large volume scintillators. Possible methods include consolidation of powders, glass-ceramics, or other approaches.

Improvements to existing commercial dual-mode gamma and neutron detection materials are needed. In addition to neutron sensitivity, gamma-ray spectroscopic performance comparable to LaBr3:Ce (light-yield ~60,000 photons/MeV and energy resolution ~3% Full Width at Half Maximum, FWHM) is sought with higher gamma-ray stopping power through higher atomic number constituents (densities exceeding 4.5 g/cm3). Low cost crystals of at least 2" are essential.

Silicon based material improvements are needed. Fabrication of very thick (~5 mm or more) silicon sensors (Charge-Coupled Device, CCDs; Complementary Metal-Oxide Semiconductor, CMOS imagers; pixel/pad/strip sensors) could be transformative in a number of nuclear nonproliferation mission areas. Reactor monitoring with ultra-low-noise (<1 e-) CCDs or CMOS imagers requires large detector mass which would be enabled by thicker devices. Very thick sensors in various readout configurations would be applicable to measurements of fission products where silicon would provide x-ray (or low energy gamma-ray), conversion electron and beta spectroscopy. Proposals to explore the potential for using direct wafer bonding of high-resistivity silicon to produce very thick, fully-depleted devices are desired. This exploratory work could utilize any of the above sensor configurations to demonstrate successful bonding, top metal application, and operation (charge collection, IV curves, charge cloud dispersion, etc.)

Questions – Contact: Donald Hornback, donald.hornback@nnsa.doe.gov

b. Improved Methods for Light Collection to Enhance Radiation Detection

Surface modification for improved light extraction using photonic coatings is needed. In currently used techniques where an optical grease is used for coupling high-index inorganic scintillators to low-index detector windows, a majority of the light generated by the interaction of a gamma-ray in the scintillator undergoes multiple total internal reflections (TIRs) before exiting to the photodetector. The resulting loss of light degrades the energy resolution (ER), and multiple total internal reflections also delay the exit of scintillation photons towards the photodetector, substantially degrading timing performance. Improving scintillator brightness, along with energy and temporal resolution is important in virtually all radiation detection applications. An alternative approach is to utilize the novel properties of nanostructures such as photonic crystals (PhCs) to modify the exit surface of the scintillator crystal increasing the fraction of usable light produced by the scintillator. Using PhC that gradually changes the refractive index between the window and photodetector, ~50% improvement in the light extraction and ~40% improvement in the energy resolution of existing inorganic scintillators, has been demonstrated using PhCs nanoimprinted in polymers. However, additional research is required for further improvements and develop a production protocol.

Development of a photocathode with very high quantum efficiency based on the bi-alkali antimonide K2CsSb is needed. Bi-alkali antimonide (K2CsSb) photocathode has one of the highest quantum efficiencies (QE) in the spectral region (250 - 400 nm) that matches well with the emission of high-light-yield gamma/neutron scintillators such as LaBr3:Ce, SrI2:Eu, Cs2LiYCl6:Ce. The development is currently limited by the production mode (growth-characterization) that impact performance. Historically, the QE for these cathodes has improved very gradually up to ~25 - 40 % and is strongly limited by the method used for producing them. Successful research and development of photocathode-growth and characterization has the potential for a major leap in the QE, which will translate seamlessly into high energy resolution (through higher photon counting) of current scintillators such as NaI without adding to cost.

Questions – Contact: Donald Hornback, donald.hornback@nnsa.doe.gov

c. Portable Advanced Neutron Imaging Capability

Associated particle imaging (API) extends the capabilities of active neutron interrogation by enabling temporal discrimination and spatial localization of radiation signatures. Proposals are sought to integrate API into the next generation of high-performance portable deuterium-tritium (DT) neutron generators. The system should include available DT neutron spectrum and the neutron yield should be variable. The system should also be capable of multimodal interrogation, including transmission radiography and induced emission (fission, elastic scatter, inelastic gamma) imaging. The alpha detector should be capable of sub-nanosecond timing and compatible with high data rate electronics. Specific alpha detector parameters of interest are: geometry (2D array), timing resolution better than 500 ps, imaging resolution less than one centimeter, field of view of at least 60 degrees, and a neutron energy of 14.1 MeV (DT). Specific generator parameters of interest are: continuous operating mode, 1×109 n/s/4π yield, power consumption less than 400 W, neutron production spot size less than 3 mm, lifetime greater than 500 hours, less than 30 lbs system weight, and compliant with the Department of Transportation shipping requirements. Proposals with minor deviations from the parameters are still encouraged to apply

Questions – Contact: Donald Hornback, donald.hornback@nnsa.doe.gov

d. Other

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

Questions – Contact: Donald Hornback, donald.hornback@nnsa.doe.gov

2. 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 STTR Phase I Applications: NO

The Office of Nuclear Detonation Detection (NDD) is seeking to improve capabilities for monitoring nuclear explosions, which are banned by several treaties and moratoria. These capabilities benefit the U.S. but may also benefit the international monitoring capabilities in the context of preparations for a Comprehensive Nuclear-Test-Ban Treaty (CTBT). These capabilities include collection of gas samples and measurement of radioxenon isotopes (beta-gamma emitters) within them.

a. Commercial Capability to Coat Beta Cells to Eliminate Memory Effect

Beta-gamma coincidence detectors have long utilized a plastic scintillator as the detection mechanism for electrons emitted during the decay of radioxenon. A key area of improvement sought for plastic scintillator beta cells is elimination of xenon diffusion into the plastic. During sample counting, when the xenon gas is in contact with the plastic scintillator for prolonged periods of time, diffusion of the xenon gas occurs and remains in the plastic for several days. As a result, subsequent samples will measure elevated count rates due to the residual gas trapped in the plastic. This elevated count rate is referred to as the "memory effect". One method of reducing this memory effect is the application of Al2O3 coatings to the surface of the plastic scintillator. While the Al2O3 coating provides a gas barrier which reduces the diffusion rate of xenon in the plastic scintillator, a corresponding decrease in the energy resolution of ~6% is observed. NDD is requesting a commercial coating capability for plastic scintillator cells which will eliminate the memory effect without reduction of energy resolution. Specifically, a commercially scalable atomic layer deposition (ALD) or similar coating process is required to uniformly coat the interior surface of a plastic scintillator cell. These cells are a 'test-tube'-shaped design consisting of an open ended cylinder of approximately 1 cm diameter, and 6 cm length.

In the final construction of the cell, a flat end cap is epoxied to the open end of the cylinder. Therefore the process will be required to coat both the interior of the cylinder and one side of the flat end-cap. The scintillator cells currently in use are composed of BC-404 polyvinyl toluene (PVT) which is thermally sensitive. BC-404 has a softening point of 70°C and experiences reduced scintillator efficiency if exposed to elevated temperatures for prolonged periods of time. Therefore, any coating procedure utilized for these cells will require reduced processing temperatures. Coatings must be of sufficient mechanical and optical quality to prevent gas diffusion into the plastic while providing sufficient transparency to maintain scintillator efficiency and energy resolution.

Grant applications responding to this topic must state (1) the current state-of-the-art, in terms of relevant specifications, as well as the performance goal of the proposed advance in terms of those same specifications; and (2) address the commercialization path of the coating capability 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.

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

b. Other

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

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

References: Subtopic a:

1. Maceira, M., Blom, P. S., MacCarthy, J. K., et al, 2017, Trends in Nuclear Explosion Monitoring Research & Development - A Physics Perspective, Los Alamos National Laboratory, p. 169. doi:10.2172/1355758 http://dx.doi.org/10.2172/1355758

2. Blackberg, L., Fay, A., Jogi, I., et al, 2011, Investigations of Surface Coatings to Reduce Memory Effect in Plastic Scintillator Detectors Used for Radioxenon Detection, Nuclear Instruments & Methods in Physics Research, Volume 656, Issue 1, p. 84-91. doi:10.1016/j.nima.2011.07.038 http://dx.doi.org/10.1016/j.nima.2011.07.038

3. Air Force Technical Applications Center, U. S. Air Force. http://www.25af.af.mil/About-Us/Fact-Sheets/Display/Article/333995/air-force-technical-applications-center/

3. HIGH PRECISION INJECTOR TO PREPARE NUCLEAR FORENSICS STANDARDS

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

The Office of Nuclear Detonation Detection (NDD) is requesting research to improve the preparation of samples for nuclear forensics studies and exercises. The application requires (1) high precision mixing of standard solutions containing radioactive materials (up to 10s of MBq) to exact (>97% accuracy) concentrations and (2) deposition of resulting liquids (microliter quantities) onto paper or other substrates with high reproducibility of quantity delivered, spot size and uniformity. Such a high precision, high reproducibility system could have potential applicability to other communities such as the pharmaceutical and food-additive industries.

a. Capability for Production of Standards of Mixed Solutions

Nuclear Forensic sample solutions to be mixed and delivered will be comprised of dilute (sub-ppb concentration) actinides, lanthanides and transition metals in mineral acids (e.g. HNO3, HCl or HF). The concentration of the acids in water media may range from dilute to highly-concentrated acid matrices. Typical acid matrix solution after mixing will be 2-4 M (molar) HNO3 and/or HCl. For demonstration of the operation and performance of equipment, non-radioactive surrogates of lanthanide and transition metal solutions in mineral acid matrices can be used. Components in contact with solution (or vapor above solutions) should be compatible with the acid matrices and not contribute to the elemental composition of the solutions due to corrosion or other degradation pathways. The ideal system would enable mixing of up to 6 solutions in parallel, however sequential solution addition may be acceptable provided desired throughput and accuracy are met.

The ideal system would also be designed to avoid cross-contamination between standard solutions. This could be achieved by designing a system that is constructed with materials that can be easily and cost effectively cleaned to mitigate cross contamination; comprised of cost effective components that can be readily replaced and dispositioned as low-level contaminated waste; or inexpensive enough to be disposed of in whole (as low-level contaminated waste) – i.e., a one-time use delivery system.

A desirable feature of an ideal system is absence of cross-contamination when switching from one standard solution to the other. The level of cross-contamination can be measured by delivery of a solution with analytes at the highest concentration typically delivered, followed by flushing, cleaning, or replacement of components, and delivery of a blank acid matrix solution. The concentration of the analytes in the final delivered blank must be below 10 ppt, or the method detection limit, whichever is lower. Ideally, the final measured concentration of the analyte should be shown to be below 10 parts-per-trillion in blank solutions, as measured by a suitable analytical method. Analytes to be tested can include uranium, cerium, neodymium, scandium, promethium and gold or platinum.

Another desirable attribute is throughput in the range of 100 mL (delivery) per 24 hours, with attended or unattended operation of the production system. It is further desired to use industry standard containers for high-precision elemental analysis measurements – i.e. 10-50 mL centrifuge/digestion tubes ¬or up to 500 mL bottles (polypropylene or Teflon®). In addition, a solution containment in order to minimize the spread of a spill, should one occur when loading/ reloading solutions would be a significant improvement. A tabletop system that can be inserted into a five-foot laboratory fume hood or fully enclosed and exhausted through suitable ventilation is also desired.

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

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

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

References: Subtopic a:

1. Inn, K. G. W., Johnson, C. M., Oldham, W., et al, 2013, The Urgent Requirement for New Radioanalytical Certfied Reference Materials for Nuclear Safeguards, Forensics, and Consequence Management, Journal of Radioanalytical and Nuclear Chemistry , Volume 296, Issue 1, p. 5-22. https://link.springer.com/article/10.1007/s10967-012-1972-y

2. Environmental Express, 2017, Digestion vessels|vials and tubes | Environmental Express. http://www.envexp.com/products/7-General_Lab_Supplies/VT-Vials_and_Tubes/CUPS5-Digestion_Vessels

3. ThermoFisher Scientific, Nalgene(TM) Narrow-Mouth Teflon(TM) PFA Bottles with Closure. https://www.thermofisher.com/order/catalog/product/1630-0004

4. Labconco, 2017, Five Foot Protector XStream Laboratory Hood 115V - Labconco, Labconco. http://www.labconco.com/product/5-protector-xstream-laboratory-hood-5/3749

4. DESIGN AND MANUFACTURING ADVANCES FOR SPACE-BASED SENSORS

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

The Office of Nuclear Detonation Detection (NDD) is seeking innovative design ideas and capabilities for application to future space-based nuclear detonation detection systems. These systems use a variety of sensors to continuously monitor the globe to detect, report, locate, and identify nuclear explosions.

a. Diffractive Optics Design & Manufacturing
Optical sensing for nuclear detonation detection involves space-based detection within the visible wavelength. Emerging optical detectors will leverage unique diffractive optics to help enhance and discriminate signals of interest from other background emitters. Because of the precision required for this program, new/innovative design and manufacturing diffractive optic techniques are being sought for their potential benefit to NDD and commercial applications with similar signal discrimination requirements.

NDD has interest in Point Spread Function (PSF) methods. Tools and techniques to tailor point spread functions to customize the irradiance profile and increase depth of focus are being investigated. The end goal of this effort would be to design and fabricate a representative of this diffractive optic able to withstand typical launch loads as specified in MIL-STD-1540 or the NASA General Environmental Verification Standard (GEVS: GSFC-STD-7000) with respect to environmental and outgassing conditions typical of space-based payloads launched and operating in space.

Grant applications responding to this topic should identify (1) their current state-of-the-art in designing and manufacturing of diffractive optics, (2) their current development and manufacturing process along with nominal time-durations per step/phase, and (3) evidence to support their ability to meet NDD-related interests. This call is focused toward already existing or emerging commercial products which could be modified or applied/enhanced for NDD applications.

Questions – Contact: Maj Alan Louie, alan.louie@nnsa.doe.gov

b. Process Advances in Integrated Circuit (IC) Manufacturing

NDD utilizes advanced integrated circuit design and manufacturing techniques for next generation space-based sensors. Advances in wafer-to-wafer bonding and die-to-wafer bonding have been leveraged to date.

NDD requests process advances in IC fabrication, specifically in high-yield Through-Silicon Vias (TSVs) applicable to CMOS manufacturing at 90nm, 45nm, or 32nm node sizes. Expectations of repeatable yields greater than 70% are being solicited as a current NDD interest.

Other IC process improvements of interest are in reticle stitching, wafer-to-wafer bonding, precision singulation, and die-to-wafer bonding for integrated circuits capable of withstanding a typical launch and space-based environment as specified in MIL-STD-1540 or the NASA General Environmental Verification Standard (GEVS: GSFC-STD-7000) with respect to environmental and outgassing conditions.

Grant applications responding to this topic should identify the following: 1) the technology of the proposed IC manufacturing process improvement, 2) International Traffic in Arms Regulations (ITAR) and/or Trusted Access Program Office (TAPO) experience, 3) the business's proven process areas related to IC manufacturing which may provide some benefit to NDD, and 4) the degree of maturity for each proven process area.

Questions – Contact: Maj Alan Louie, alan.louie@nnsa.doe.gov

c. Structural Materials Made with Additive Manufacturing Techniques

Additively manufactured (AM) parts offer many advantages over traditional production in specialized fabrication such as material efficiency. However there has been little research into utilizing AM to produce radiation (RAD) hardened-parts in a single build process. With the advent of dual-metal 3D printing, producing mission-specific parts that are also RAD hardened in a single step is now feasible. The combination of the part production and RAD hardening process could lead to further manufacturing efficiencies in several applications. NDD is requesting research in AM to fabricate a low-mass metal box with a high-Z alloy. The low mass box must be able to withstand typical launch loads as specified in MIL-STD-1540 or the NASA General Environmental Verification Standard (GEVS: GSFC-STD-7000). The box materials must provide improvements over the Aluminum Dose Depth Curve (e.g., withstand a greater total ionizing dose than aluminum – ideally at least 15kRad) to enable use of lower radiation qualified components inside the box for space environments requiring a tolerance to 25 kRad total ionizing dose. Part development and qualification would offer insight into the limitations and capabilities of using a single-step process AM technology to make metal boxes with structural integrity using a radiation shielding metal alloy.

Questions – Contact: Maj. Alan Louie, alan.louie@nnsa.doe.gov

d. Other

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

Questions – contact Maj Alan Louie, alan.louie@nnsa.doe.gov

References: Subtopic a:

1. Falcón, R., Goudail, F., Kulcsár, C., et al, 2017, Performance Limits of Binary Annular Phase Masks Codesigned for Depth-of-Field Extension, Optical Engineering, Volume 56, Issue 6, 065104. http://dx.doi.org/10.1117/1.OE.56.6.065104

2. HOLOEYE, 2017, Diffractive Optical Elements, HOLOEYE Photonics AG. https://holoeye.com/diffractive-optics/

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1. 3DIC.org, 2017, Direct Bond Interconnect definition. http://www.3dic.org/DBI

2. EVG, 2014, Ziptronix and EV Group Demonstrate Submicron Accuracies for Wafer-to-Wafer Hybrid Bonding, EV Group. https://www.evgroup.com/en/about/news/2014_05_Ziptronix

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1. Los Alamos National Laboratory, 2017, Additive Manufacturing: A Method Allowing Unparalleled Manufacturing Control, Data Visualization, and High-value Parts Repair, LANS, LLC. http://www.lanl.gov/org/padste/adeps/materials-science-technology/programs/additive-manufacturing/index.php

2. Davies, S., 2017, NASA Reveals 3D Printing of Radiation Shields on Bigelow Expandable Activity Module, TCT Magazine. https://www.tctmagazine.com/3D-printing-news/nasa-radiation-shields-bigelow-expandable-activity-module/

3. Wrobel, J., Hoyt, R., Cushing, J., et al, 2013, Versatile Structural Radiation Shielding and Thermal Insulation through Additive Manufacturing, Tethers Unlimited, Inc., p. 9. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2926&context=smallsat

4. Thomsen, D. L., Kim, W., Miller, N. A., et al, 2014, Shields-1, A CubeSat with a Radiation Shielding Research Payload, National Aeronautics and Space Administration, p. 20. http://mstl.atl.calpoly.edu/~bklofas/Presentations/DevelopersWorkshop2014/Thomsen_Shields-1.pdf

References: Subtopic d:

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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.

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. OE leverages effective partnerships, solid research, and best practices to address diverse interests in achieving economic, societal, and environmental objectives.

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.

5. 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 STTR Phase I Applications: NO

The electric power grid is facing increasing stress due to fundamental changes in both supply-side and demand-side technologies. On the supply-side, there is a shift from large synchronous generators (e.g., coal, nuclear) to smaller units (e.g., gas-fired turbines) and variable energy resources (e.g., renewables). On the demand-side, there is a growing number of distributed energy resources, as well as the increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The monitoring and control systems used for operations are also transitioning from analog systems to systems with increasing data streams and more digital control and communications; from systems with a handful of control points at central stations to ones with potentially millions of control points. In essence, the grid we have today was not designed for today's requirements.

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 and enable the application of intelligent devices, next-generation components, cybersecurity protections, advanced grid modeling and applications, distributed energy resources, and innovative architectures. Integration of these technologies will require a new communication and control layer to manage a changing mix of supply- and demand-side resources, evolving threats, and to provide new services.

All applications to subtopics under this topic should:

- 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.
- Emphasize the commercialization potential of the overall effort and 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/or experimental data.

Grant applications are sought in the following subtopics:

a. Innovative Technologies to Mitigate Experienced-Workforce Shortages

A big challenge electric utilities will be facing in the foreseeable future is a workforce that is rapidly retiring and the loss of institutional knowledge. This will create a vulnerability in the electric grid, especially during widespread power outages where recovery efforts relies on a team of well-trained and experienced personnel. During these critical situations, it will be inefficient and time consuming to have a person with the relevant experience physically travel to several locations to support recovery. This issue will be exacerbated with a shortage of experienced personnel.

This subtopic is looking for innovative technology solutions, such as augmented reality or virtual reality, which can be adapted to enable a small number of experienced-personnel to supervise or train the electric utility workforce of the future. For example, a potential solution would allow one person to remotely supervise multiple crews in widespread locations by virtually moving from one crew to another in a matter of seconds. Other potential applications include the ability to access information in the field, in real-time, needed to perform work such as virtual instructions or manuals; the ability to "see" hard to access data and information; and the ability to rapidly process information and other digitized data. The aforementioned applications will allow both experienced and less experienced personnel to perform work more efficiently.

For this subtopic, proposed solutions should have:

- Real-time visual capability
- Real-time audio capability
- Interoperability with other technologies

Applicants are encouraged to consider capabilities and applications such as those described in this subtopic as well as other innovative ideas not addressed here.

Questions – Contact: Stewart Cedres, stewart.cedres@hq.doe.gov

b. Advanced Protective Relaying Technologies and Tools

IEEE defines a protective relay as "a relay whose function is to detect defective lines or apparatus or other power system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action." As the electric power system continues to evolve, there are several challenges that require advances in protective relaying solutions to ensure the safe and reliable operation of the grid.

Protective relaying technology has evolved from being based on electromechanical devices, to solid state, and more recently microprocessors. While the technology has increased in accuracy and functionality, there has also been a reduction in their life expectancy. Reasons for the shorter life range from thermal effects of power supplies to contact material degradation. Another concern deals with greater penetration of distributed energy resources (DERs) that can result in reverse power flows in the distribution system. Protective relay set-points are based on the assumption that the utility will supply fault currents but the contributions from DERs may result in failure to operate. Other examples of misoperations can be found in the NERC Glossary of Terms (see references).

Ultimately, degraded relay performance due to age, improper settings, misoperations, and inaccuracies present a hazard to the public and utility workers. This subtopic is looking to develop technologies, methodologies, processes, materials, or tools that will advance the state of the art of protective relaying.

Desired characteristics and capabilities include:

- Longer life spans (e.g., 30-40 years)
- Dynamic, adaptive set-points
- Self-diagnostics
- Lower costs
- Detection and prevention of misoperation
- Improved fault detection and location

Collaboration with protection device manufacturers and utility protection engineers is strongly encouraged.

Questions – Contact: David Howard, david.howard@hq.doe.gov

c. Advanced Magnetics for Next Generation Power Converters Used in Grid-Tied Energy Storage Systems

Energy storage systems are becoming more prevalent in electric utility applications by providing advanced functions such as frequency regulation, power quality enhancement, and dynamic stability support. The enabling technology crucial to these applications is the power conversion system. With the recent advances in wide band gap (WBG) semiconductor devices (e.g., SiC and GaN), new converter topologies are emerging that leverage their high switching frequency, high junction temperature, and high breakdown voltage capabilities. For example, high frequency (10 to 200 kHz) link converters with dual active bridge technology can significantly reduce the size of the system while providing galvanic isolation.

However, the magnetic cores available today are not optimized for high frequency applications. For example, soft ferrites are low cost with reasonable loss performance but suffer from a low saturation magnetic polarization (Js), which severely limits their power handling capability. On the other hand, silicon steels offer a high Js but are plagued by large losses at high frequency. Some of the best performing materials in terms of losses at high frequency are amorphous and nanocrystalline Fe and Co based alloys. However, the Js of these materials falls short of silicon steel and their manufacturing processes drives up cost, limiting their widespread use.

Additionally, most energy storage power conversion systems offer 3-phase AC output at 480-VAC with a DC input voltage range of 600 to 1000-VDC. A 60 Hz transformer is generally used to step up the 480-VAC output to higher voltages for grid connection. The generated waveform from these converters are not a perfect sinusoid and contains harmonics, which can wreak havoc on step-up transformers and other equipment. Passive filter are typical used to address this issue but the inductive core materials are plagued by many of the same issues faced in the high frequency link converters.

This subtopic is looking for advanced magnetic materials suitable for WBG-based converters applications with power rating of greater than 100 kW and associated passive filters.

Materials will need to have:

- Lower losses in the 10-200 kHz frequency range compared to alternatives
- High magnetizing polarization to be robust against saturation (Js > 1.8 T)
- Lower costs when manufactured at scale compared to alternatives (e.g., soft ferrites)
- In the filter application, the ability to withstand a wide range of frequency harmonics while limiting reactive power generation, losses, and even worse saturation

Questions – Contact: Imre Gyuk, imre.gyuk@hq.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

DOE's Office of Energy Efficiency and Renewable Energy (EERE) supports early-stage research and development of energy efficiency and renewable energy technologies that make energy more affordable and strengthen the reliability, resilience, and security of the U.S. electric grid..

EERE's Technology Office activities are conducted in partnership with the private sector (including small businesses), DOE national laboratories, universities, and state and local governments. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices. EERE's fiscal year 2018 budget request can be found here: https://www5.eere.energy.gov/office_eere/current_budget.php.

6. ADVANCED MANUFACTURING I

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

The Advanced Manufacturing Office (AMO) (https://energy.gov/eere/amo) collaborates 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.

Applications may be submitted to any one of the subtopics listed below 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. MYPP or Roadmap 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. Intelligent Systems for Materials Design and Discovery

Combinatorial and other high-throughput methods of materials screening provide rapid analyses of large numbers of samples of diverse materials such as coatings, catalysts, and pharmaceuticals. Although these methods provide vast amounts of information, they are unable to elucidate any underlying mechanisms nor the process for discovering new materials.

The availability of increasing digital computational capabilities and algorithms has dramatically expanded the possibilities for artificial intelligence and machine learning applications in materials design and discovery. Combining advanced computing capabilities physics based models in a single platform would greatly aid in advanced materials research and discovery.

Investigators from small businesses are invited to collaborate with researchers in the materials and computational sciences to develop systems that are aided by artificial intelligence to expand the ease and scope of high throughput discovery methods. This subtopics' objective is to make materials discovery methods more accessible to investigators who need to develop or improve new materials. This subtopic aims to allow for the interpretation of data with machine learning to direct the materials search toward desired objectives.

It is expected that the result of this effort will be a system that can be commercialized and sold to investigators with specific, proprietary materials development objectives and needs. In addition, an open-source platform can be developed to share with the greater research community, hosted in a forum such as GitHub.

Interdisciplinary teams of investigators are invited to submit research proposals for intelligent systems development in the following areas:

- Heterogeneous catalyst discovery: All types of heterogeneous catalysts are covered by this subtopic area, including but not limited to fuel cell electrocataysts and catalysts used in industrial chemistry.
- Polymer discovery: Large numbers of polymer samples are typically analyzed for various coatings and other applications. Intelligent systems would greatly reduce the time needed in combinatorial searches of polymeric materials for a desired end use.
- Thin films for energy applications: Applications for thin film semiconductor and dielectrics used in photovoltaic applications, fuel cells, etc. are solicited.
- Other energy related materials: Including but not limited to materials for thermoelectrics, thermocalorics, magnetic materials, and supercapacitors.
- Specialty organic compounds: Compounds that have application in diverse end uses, such as the food and drug industries, and exhibit subtle differences in their specific chemistries by their composition and configurations.

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

b. Novel Energy-Efficient Dewatering Methods for Cellulosic Nanomaterials

Cellulosic nanomaterial (CNC and CNF) production has transitioned from laboratory to pilot scale, making it feasible for their use in a variety of industrial applications; including oil and gas, wastewater treatment, electronics and others. A significant hindrance for further advancement is their difficulty when drying, as CNCs and CNFs are not economical to ship long distances while containing significant water content [1]. We seek novel, energy-efficient, dewatering or drying methods that would maintain material properties, such as particle size, when dried and redispersed [2]. Applications are welcome to propose novel heating systems, heat transfer systems, dehumidification, or chemical treatments, however; it is reported that mechanical dewatering techniques do not appear to be economical [3].

Applications must focus on the production of dewatered/dried product at high yield using an economic energy source that is available at competitive industrial rates. The novel method should not be primarily dependent on heat recovery, and must not include production of byproduct power for sale to achieve the proposed energy efficiency and cost metrics. That is, factors such as heating method, heat transfer, containment device, dewatering/drying system design, and material treatments should be novel. Material handling systems, storage, material supply and shipment requirements should be considered. The application should include a clear initial economic analysis and methodology to estimate drying cost per unit of product produced and compare to an existing drying method [4]. Successful applicants must demonstrate experience with drying technology.

The materials, when ready for shipment, should be suitable for high volume applications, such as fiber reinforcements for thermoplastic products. The application(s) must define the intended end use(s) for the dried product, and demonstrate knowledge of the manufacturing and end use requirements of those applications. The preliminary economic analysis should include an estimate of product demand, while the Phase I work would include a task for a detailed economic analysis as well as a concept design for the novel dewatering/drying technology. The application should identify the key technical challenge(s) and show how proof-of-feasibility with statistically meaningful data to support yield, efficiency, and drying capacity capabilities will be developed.

Questions – Contact: Stephen Sikirica, stephen.sikirica@ee.doe.gov

c. Thermal Process Intensification for Productivity Improvements

Process heating accounts for more direct energy use than any other energy consuming processes in manufacturing, but traditional industrial (thermal) processes can be inefficient, difficult to control and result in materials and products with compromised quality and performance [1]. As such, new and innovative approaches are sought that use low/no direct application of heat to transform materials into higher value products. For example, since electromagnetic (EM) energy interacts with different materials in unique ways, EM technologies (electrotechnologies) have the potential to unleash enhanced or entirely new manufactured products and materials as well as new approaches and processes for producing such materials. While there are some examples of electrotechnologies that have been adopted by the manufacturing sector where mechanisms are well understood (e.g. dielectric heating as the mechanism for rubber curing by microwave and adhesive curing by radio-frequency), but uptake is limited. In addition, there is a vast EM spectrum that can be harnessed, there are other wave/material mechanisms that could enable new applications, and the potential of hybrid technologies has not been capitalized upon. For example, the development of integrated, enhanced and compact process equipment to synergistically intensify thermal, mass and momentum processes, has the potential to significantly improve advanced manufacturing energy productivity [2]. There are a number of inter-related opportunities for greater utilization of EM technologies and other low/no thermal budget technologies; grant applications are sought to develop new approaches targeting areas/issues including:

- Process/Equipment Co-Development: Since the material (to be processed) becomes an integral part of the overall system, the equipment design is far more critical than in traditional (heating) processes, leading to increased up-front costs. Modeling and Simulation is an integral part of this process.
- Modeling and Simulation: Complex EM wave/material interactions plus coupled heat and mass transfer that varies by material hinders uptake by industry, especially for new applications, as special skills are required to for simulations, design, engineering, etc.
- Process Scale-Up: There are different low TRL technological barriers that exist at different scales; e.g., solving a technological barrier at small-scale does may not address a barrier at large-scale.
- Equipment Scale-Up: To date, equipment scale-up has been limited. Advances in cost effective user-friendly equipment for industrial and manufacturing markets are needed. For example, cost effective production-scale solid-state power supplies need to be integrated during process/equipment co-development.

- Equipment Scale-Down: In some cases, more compact, more efficient and less expensive technologies – such as small-scale accelerators – could lead to advances in precision, user-friendly equipment for industrial and manufacturing markets.
- Integral Control Systems: Real-time, in-situ and integrated process monitoring and control systems for thermal process intensification that are part of a broader Smart Manufacturing strategy [3].

Grant applications are sought to develop novel means for thermal process intensification technologies to improve manufacturing energy productivity. Successful applicants should: (1) identify what fundamental science gaps exist and what new knowledge will be acquired; (2) specify which industry is targeted and provide a clear and concise justification of why the new process/technology best meets the specific requirements of that application; (3) demonstrate that the proposed approach will have an impact on overall energy productivity; (4) include an economic analysis that accounts for long-term implications; and (5) demonstrate the ability of the applicant to proceed to a demonstration of technology viability under a Phase II project.

Questions – Contact: Joe Cresko, joe.cresko@ee.doe.gov

d. TECHNOLOGY TRANSFER OPPORTUNITY: Process for the Synthesis of Precision Nanoparticles

Supercritical fluid extraction offers a more environmentally friendly, cost-competitive process for producing nanoparticles than traditional methods, which include attrition, pyrolysis and hydrothermal synthesis. By exposing single-source precursors — molecules containing elements connected by a single chemical bond — to carbon dioxide in a supercritical state, researchers at Idaho National Laboratory and Idaho State University have developed a process to produce uniform nanoparticles at desired sizes ranging from 1nm to 100nm (+/- 0.2nm). Instead of using high temperature, the process takes place at around 65 degrees Celsius, saving significant amounts of energy. While the patented method using supercritical fluids was originally conceived as a process for making nanomaterials for cost-effective and high efficiency photovoltaic cells, the process is recognized to have potential in producing nanoparticle based materials for microelectronics, magnets, thermoelectric devices, and also for catalysts in the advanced manufacturing of platform chemicals. The promise of this breakthrough technology was recognized in 2009 with an R&D 100 Award.

This Technology Transfer Opportunity seeks to leverage the precision nanoparticle technology developed at INL and ISU for the commercialization of a process to synthesize new catalyst, thermoelectric and/or semiconductor materials. The ideal candidate for this TTO opportunity will have identified target material compositions with the desired stoichiometry and crystalline structure(s) of the desired nanoparticle product(s). The targeted outcome will be demonstrating the feasibility of using the precision nanoparticle process for the production of nanoparticle based materials.

For more information please visit:
https://techportal.eere.energy.gov/technology.do/techID=886
https://factsheets.inl.gov/FactSheets/Precision_Nanoparticles.pdf

Licensing Information
Idaho National Laboratory Information
Contact: Ryan Bills (ryan.bills@inl.gov; 208-526-1896)
License type: Exclusive or Non-Exclusive, please include description of intended field of use in proposal.

Patent Status: U.S. Patent No 8,003,070 - Methods for forming particles from single source precursors, Issued August 23, 2011.

Questions – Contact: Tara Gonzalez, tara.gonzalez@ee.doe.gov

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7. ADVANCED MANUFACTURING II: ATOMICALLY PRECISE MANUFACTURING

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

The Advanced Manufacturing Office (AMO) (https://energy.gov/eere/amo) collaborates 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.

Applications may be submitted to any one of the subtopics listed below 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. MYPP or Roadmap 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.

Atomically precise manufacturing is the production of materials, structures, devices, and finished goods in a manner such that every atom is at its specified location relative to the other atoms, and in which there are no defects, missing atoms, extra atoms, or incorrect (impurity) atoms. A roadmap describing pathways and applications was published in 2007 [1]. At an Advanced Manufacturing Office workshop in Berkeley in 2015 [2], participants identified two specific positional assembly methods for achieving this extraordinary level of precision: (1) tip-based positional assembly using scanning probe microscopes, and (2) integrated nanosystems using molecular machine components.

Both approaches have considerable challenges to implementation, including positional accuracy (which is influenced by factors such as component stiffness and thermal vibration), repeatability, working tip design and synthesis, suitable building block design, transport of molecules to the working tip, and scalability. New molecular components must be developed for integrated nanosystems, as well as new and advanced techniques to assemble these components.

Grant applications are sought in the following subtopic:

a. Molecular Machine Advances

Molecular machines have received considerable attention in recent years, notably for the 2016 Nobel Prize in Chemistry [3] and the Nanocar race competition [4]. In biological systems, molecular machines such as ribosomes, DNA polymerase, and ATP synthase are able to process molecules to build new molecules. The bacterial flagellar motor is an elegant example of an atomically precise molecular machine that is able to convert the transport of ions into motion [5, 6]. Molecular machines such as the actin-myosin system in human muscles operate as part of a coordinated network to effect motion at the macroscale. In similar fashion, it is the integration and coordination of molecular machines that will propel key advances in atomically precise manufacturing.

Advances in molecular machine design and integration will be considered for funding. A 5-year goal could be an integrated nanosystem [2] that would:

- transport individual feedstock molecules to a workspace (actively or passively);
- modify or chemically activate the feedstock (if required) to prepare it for an assembly operation;
- manipulate or transport the feedstock to the attachment point at a specified atomic position;
- chemically bind the feedstock to a growing structure or device at that attachment point; and
- repeat the operation a sufficient number of times to synthesize a product with no defects.

By addressing a critical pathway toward enabling new materials with an order of magnitude improvement in strength (near the theoretical limits), this research provides the platform to enable the military of the future with materials that can't be engineered today. These ultra-strong materials would similarly find application in transportation lightweighting. Other high impact energy applications include atomically precise catalysts for chemical processes and atomically precise membranes for desalination (Energy-Water Nexus). This foundational technology also supports American security by enabling advanced molecular electronic computer circuits and quantum computer circuits for cryptographic applications, by advancing high sensitivity molecular sensors for chemical threat detection, and by enabling new chemical processing methods for chemical threat remediation.

Responsive proposals will identify specific technological hurdles in their approach to design, synthesize, and demonstrate an integrated system of molecular machine components, and show how the milestones and deliverables proposed for the project will overcome these hurdles. Physical realization of integrated molecular machine components is the preferred deliverable, however the Phase I proposal may experimentally demonstrate overcoming issues at the subcomponent level that eventually lead to the desired advance in integrated nanosystems. For example, designing and building a critical molecular machine component would be responsive, if the proposal shows how this component would function as part of an integrated nanosystem for molecular assembly in a Phase II demonstration. Theoretical studies alone will not be considered responsive to this solicitation, although may be proposed in complement to experimental demonstrations.

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

References: Subtopic a:

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8. BIOENERGY

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

The Bioenergy Technologies Office (BETO) has a mission to advance a thriving and sustainable bioeconomy fueled by innovative technologies (https://energy.gov/eere/bioenergy/bioenergy-technologies-office). As part of this mission, BETO is interested in receiving proposals in any one of the subtopics listed below. The U.S. Department of Energy hopes to exploit the deployment of cheaper and cleaner renewable power as well as novel cell-free biotechnologies to substantially increase the overall carbon efficiency of biomass conversion, and is seeking grant applications that propose to demonstrate new technologies and engineered systems that take advantage of these new conditions and/or technologies to produce a final biofuel or enabling bioproduct. Ultimately, creative pathways and system designs that take advantage of the stipulated conditions and/or new biotechnologies are sought regardless of which manner carbon conversion efficiency is enhanced.

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. MYPP or Roadmap 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 and;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Biofuels and Bioproducts from Wet Organic Waste Streams at Relevant Scales

Wet organic waste streams represent valuable potential feedstocks for the Bioeconomy of the Future. They include, but are not limited to, municipal sludges and biosolids, industrial, commercial, and residential food wastes, manure slurries, fats, oils, and greases, byproducts from ethanol production, and other feedstocks not suitable for food uses. These feedstocks often present a clear and present disposal problem for municipalities and similar responsible parties. Further, in many cases, they are already being collected as part of existing waste management practices. While some of the available energy is currently being captured, a significant amount remains untapped [1-3]. These resources thus offer potential opportunity for conversion into biofuels and bioproducts.

However, these feedstocks are not produced at the scale of traditional petroleum refineries. Further, given their high moisture content, long-distance transportation is rarely economically viable. This implies the need for conversion strategies that are techno-economically feasible at scales that match the available feedstock volumes [4, 5]. While traditional anaerobic digestion is a proven technology, the required capital expense presents challenges at scales smaller than 5 dry tons/day [3]. Thus, there is a practical need for novel alternatives to anaerobic digestion that have the potential to compete economically with feeds of one dry ton/day or less. Of course, novel solutions have to compete with existing practices [2, 6, 7]; proposals that demonstrate awareness of their competitive position with respect to the current environment are especially welcomed.

There are a number of intriguing techno-economic possibilities in this problem space, including but not limited to:

1. Anaerobic Membrane Bioreactors (AnMBRs) of various designs [8-11]
2. A wide range of solutions involving Microbial Electrosynthesis, including some in combination with AnMBRs [12-16]
3. Feedstock blending strategies with the potential to improve the viability of smaller-scale operations [7, 17]. Proposals in this area would need to emphasize why their proposed solution improves on the current state of the art with respect to co-digestion.
4. Biological processes that produce Volatile Fatty Acids (VFAs) or other biofuel and bioproduct precursors other than biogas from relevant feedstocks [18, 19]. Proposals that successfully address separations issues and potential product toxicity would be particularly welcomed [7, 20].
5. Proposed solutions that combine some mix of thermochemical, electrochemical, and biological strategies in a coherent way with a reasonable prospect of delivering cost-effective results [16].

This list is not exclusive. The DOE seeks proposals with a reasonable chance of producing techno-economically viable biofuels and bioproducts from wet organic waste streams at relevant scales within the timeframe of the SBIR program, and is very open to solutions not included in the enumeration above.

Restrictions and Requirements:
Feedstocks:

- Responsive applications will have proposed systems that utilize wet organic waste streams as the primary feedstock to produce fuels, or fuel and product mixtures. Proposed projects should employ actual (rather than model or synthetic) waste streams as feedstocks by the end of phase II.
- Nonresponsive applications will have proposed systems that:
  - Utilized a feedstock that could be processed to inputs for food or feed, including waste glycerol from biodiesel processes
  - Utilize algae, even if that algae were grown on wastewater, and dry waste streams, such as corn stover, or the woody fractions of municipal solid waste
  - Utilize feedstocks that are commercially employed, such as yellow grease to produce biodiesel. Brown grease is a responsive feedstock.

Products:

- The DOE is interested in projects that present the possibility of producing commercially relevant and economically competitive higher hydrocarbons and oxygenates from biogenic sources to displace imported petroleum. Examples include, but are by no means limited to, 1,3-butadiene, 1,4-butanediol, and medium or higher chain fatty acids. Higher carbon number hydrocarbons and alcohols in the jet and diesel range are particularly encouraged.
- Hydrogen, ethanol, methane, syngas, and methanol are not allowed as end products, but are acceptable as intermediates, if the proposal is clear how the intermediates will be incorporated into processes to produce biofuels or bioproduct precursors by the completion of phase II.
- Applications that propose syngas as an intermediate must include a clear strategy for developing an end-to-end process to produce biofuels and bioproducts at relevant scales, and should include a demonstration of same by the completion of phase II.
- Renewable diesel is strongly preferred over biodiesel as an end product.
- Additionally, proposals that strive to complete the conversion of relevant feedstocks to jet or diesel blend stocks suitable for incorporation into existing refinery processes by the end of the proposed project are particularly encouraged.

Systems:

- Successful applications will propose to develop and run pilot systems at a relevant scale (e.g., 5–50 L reactor volume) by the end of phase II.

Questions – Contact: David Babson, david.babson@ee.doe.gov

b. Rewiring Biomass Conversion: Novel Strategies to Substantially Enhance Biomass Carbon Conversion Efficiency

Achieving biomass demands to maintain a robust and growing bioeconomy sustainably will place additional burdens on fertile land required for terrestrial crop production [1], and will necessitate increasing the land's effective product yield [2]. Biomass conversion technologies can be optimized to maximize carbon conversion efficiency in which the greatest amount of feedstock carbon is directed to desired products without unnecessary CO_2 evolution or side reactions, and, in the case of biologically catalyzed conversions, excessive biomass accumulation during fermentation.

There are a number of strategies that could be pursued to substantially enhance the carbon efficiency of biomass conversion processes. Some include, but are not limited to, 1) cell-free biocatalytic systems that avoid carbon needs for bioreactor biomass accumulation [3], 2) traditional whole-cell platforms that have engineered mixotrophic pathways designed to direct otherwise wasted CO_2 to fuels and products [4], and 3) engineered platforms using mixed microbial consortia designed to consolidate multiple reaction steps and perform disparate conversions simultaneously.

An important consideration for designing future biomass and chemical conversion systems is the large-scale and rapid deployment of renewable power such as wind and solar, which is driving down the cost of power [5], and presenting an opportunity to leverage cheap electricity to enhance carbon conversion efficiency. Enhancing the carbon conversion efficiency of biomass systems through the strategic use of electricity could serve as a mechanism to substantially increase the effective land yield of renewable carbon for a growing bioeconomy, and – in some configurations – offer opportunities to enhance grid reliability and stability by allowing for dynamic energy storage in carbon bonds [6] [7].

The U.S. Department of Energy hopes to exploit cheap, domestic power as well as novel cell-free biotechnologies to substantially increase the overall carbon efficiency of biomass conversion, and is seeking grant applications that propose to demonstrate new technologies and engineered systems that take advantage of these new conditions and/or technologies to produce a final biofuel or enabling bioproduct.

Ultimately, creative pathways and system designs that take advantage of the stipulated conditions and/or new biotechnologies are sought regardless of which manner carbon conversion efficiency is enhanced. Other items for applicants to consider include:

- Although the engineered system can combine multiple conversion technologies, the overall conversion process being optimized must make use of a biocatalytic step.
- The biocatalytic step(s) can be “cell-free”, meaning that it can be catalyzed by an extracellular enzyme and does not require a viable organism.
- While applicants can assume that the electricity used is both cheap/surplus and low-carbon, applications should address the energy efficiency of the system while understanding that carbon conversion efficiency is paramount.
- Successful applications will minimize the ratio of required energy inputs to the energy potential of proposed outputs and justify greater electrical requirements with greater biomass carbon conversion efficiencies.
- Beyond electricity, other external system energy sources, such as H_2, are encouraged as long as electricity is assumed to facilitate its production and this step is included in any techno-economic and life-cycle assessments. No renewable energy or carbon credits may be included in such assessments.
- Beyond “carbon efficiency”, applicants should consider “biomass efficiency” by selecting products and processing routes that take advantage of inherent structural and compositional qualities of the biomass feedstock.
- All non-food biomass are responsive as well as:
    - Cellulosic biomass, cellulosic hydrolysates, organic wet wastes, wastewater and wastewater solids
    - Biogas
    - Reduced carbon intermediates from the direct reduction of atmospheric or industrially emitted CO_2
- Systems that utilize biogas should address directing both CH_4 and CO_2 to products in order to enhance the system’s overall carbon efficiency.
- Hydrogen, ethanol, methane, syngas, and methanol are not allowed as end products, but are acceptable as intermediates, if the proposal is clear how the intermediates will be incorporated into product.
- Successful applications should propose technologies that, by the end of Phase II, could operate at a sizeable biomass throughput at 100 L reactor volume and preferably greater.
- By the end of Phase II, projects must present a preliminary techno-economic analysis (TEA) which associates minimum fuel selling prices (MFSPs) to various electricity and carbon prices, and specifically what prices (perhaps even negative electricity and carbon prices) that offer fuel products at or below $3/GGE. Successful applications will outline how such a TEA will be performed and highlight data to be obtained in Phases I and II that would enable the needed analysis.

Questions – Contact: David Babson, david.babson@ee.doe.gov

c. Algae Breeding

Improvement of algal strains to achieve desired operational traits such as high yield, biomass product optimization, robust resistance to pathogens and other stressors, and ease of harvest has advanced greatly in the past few years due to the use of advanced biotechnology tools such as CRISPR/Cas9 gene editing, growing databases of genome sequences, integrated transcriptomics studies, and traditional genetic engineering approaches. However, robust approaches for inducing sexual recombination or mating, developing marker assisted breeding, mapping quantitative trait loci (QTL) linkages, back-crossing to stabilize homozygous lines, and the development of sterile lines to fix traits- all hallmarks of modern crop improvement - are notably lacking in algal approaches to strain improvement. These traditional plant breeding approaches show great promise for improving algal strains. [1]

The purpose of this sub-topic is to develop tools for breeding algae through traditional approaches to improve phenotypes of interest such as product yield, growth rates, harvest performance, and robustness in culture. Tools of interest are:

- High resolution marker databases for strains of interest
- Approaches for back crossing and developing homozygosity
- Improved phenotypes
- Manipulating genetic linkage groups to enhance the stability of introduced traits, and
- Developing sterility systems to fix traits

Other breeding approaches may be considered. For all approaches, the ultimate objective should be an improvement over baseline performance of the wild-type strain without the application of genetic engineering through the developed breeding approaches.

Questions – Contact: Devinn Lambert, Devinn.lambert@ee.doe.gov

d. Solid-Liquid Separations for Algal Systems

Capital and operational cost reductions are required for algal energy to become widespread. The cost of solid-liquid separation, including algae concentration and dewatering, is a critical driver for initial capital, energy and resource costs of algal fuel and products. Algae grown in open ponds and photobioreactors are dilute (0.1–0.5 grams per liter) and currently require multiple concentration steps. Multiple separation technologies might substitute for these multiple process steps, but only if these technologies are integrated in an optimal (unit operation) fashion.

The purpose of this subtopic is to integrate commercial processing technologies as a unit operation that produces slurry with 20–30% solids from a dilute (0.5 grams/liter or less) algal feed. The applicant should consider as a minimum the following technology options for integration:

- Vacuum Filters
- Membranes
- Pressure Filters
- Hydroclones
- Screens and or sieving, and
- Gravity tables

Other technologies, such as flocculation, may be considered, provided the evaluations in the application consider the cost of the chemicals. For the required comparison of energy and cost parameters, the applicant must use – as a baseline – the integration of dissolved air floatation with centrifuges to achieve the desired solids concentration. Applications must show a final 25–30% reduction in capital cost [1], a 20% reduction in energy demand, and a solids concentration of at least 20%.

Questions – Contact: Devinn Lambert, Devinn.lambert@ee.doe.gov

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9. BUILDINGS

Maximum Phase I Award Amount: $150,000	Maximum Phase II Award Amount: $1,000,000

Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Residential and commercial buildings account for more than 40% of the nation's total energy demand and 70% of electricity use, resulting in an annual national energy bill totaling more than $430 billion. The U.S. Department of Energy's Building Technologies Office (BTO) (http://energy.gov/eere/buildings) is working in partnership with industry, academia, national laboratories, and other stakeholders to develop innovative, cost-effective energy saving technologies that could lead to a significant reduction in building energy consumption and improve the grid's reliability by reducing its sensitivity to sudden supply shortfalls. BTO's goal is to reduce aggregate building energy use intensity by 30% by 2020 and by 45% by 2030, relative to the consumption of 2010 energy-efficient technologies. The rapid development of next-generation building technologies are vital to advance building systems and components that are cost-competitive in the market, to meet BTO's building energy use reduction goals, and lead to the creation of new business and industries. Moreover, by cutting the energy use of U.S. buildings by 20%, the American people could save approximately $80 billion annually on energy bills. And, money saved on energy costs flows to other sectors of the economy, which can lead to the creation of new jobs.

Applications may be submitted to any one of the subtopics listed below 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. Multi-Year Program Plan (MYPP) or Roadmap 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 an energy savings impact and preliminary cost analysis;
- Fully justify all performance claims with thoughtful theoretical predictions or experimental data.

Grant applications are sought in the following subtopics:

a. Innovations in Opaque Building Envelope Performance

More than 40% of US primary energy and 70% of electricity was consumed in residential and commercial buildings, resulting in annual energy costs of more than $430 billion. Approximately 35% of this consumption can be attributed to losses through the building envelope, via heat transfer and air infiltration. More than 25% of that energy, or 10% of total energy use in buildings, is lost due to air infiltration alone. The building envelope (e.g., walls, roof, foundation, and windows) being the thermal and mass barrier between the interior and outdoor environment, is thus one of the primary determinants of energy use to maintain comfort and safety. As a result, developing innovative building envelope solutions that efficiently reduce and manage energy is paramount to achieve BTO building energy use reduction goals. To this end, BTO seeks to develop and accelerate next-generation building envelope technologies that reduce the amount of energy lost through the building envelope, contribute to improved occupant comfort, and have low product and installation costs to enable market adoption.

BTO is seeking proposals for high-performance and cost-effective building envelope technology innovations with the potential to enable significant reductions in cooling and heating loads. This is an open opaque building envelope subtopic and areas of interest include, but are not limited to, the following:

- **Separation Technologies:** Low cost separation technologies, such as innovative membranes and adsorption technologies, capable of significantly improving building energy efficiency and enhanced performance of building envelopes. Examples could be smart envelopes for energy efficient dehumidification to enable occupant comfort and envelope durability.

- **High-Performance Thermal Insulation Technologies for Retrofitting Existing Buildings:** Low cost > R-12/inch (k = 0.012 W/m•K) or higher building envelope thermal insulation that can be added to walls of existing buildings with a simple payback period for retrofit projects ideally less than 5 years but no more than 10 years. Insulation materials must be able to meet existing durability (fire, structure, moisture, acoustic code) requirements, and minimize occupant disturbance (e.g., amenable to quick and easy installation compared to existing technologies). This material must be applicable for wall insulation, but can also be applicable for other portions of the envelope. The insulation innovation should have a simple low-cost, scalable manufacturing process to develop a viable retrofit insulation that provides high R/inch thermal insulation cost-effectively.

- **Self-healing or puncture mitigating solutions for vacuum insulation panels (VIP) or modified atmosphere insulation (MAI):** VIP and MAI panels consist of an open-pore material that is vacuum-enveloped by a barrier foil that prevents the entry of air and water vapor and can attain R/inch values over 35. However, because they are vacuum-enveloped, VIPs and MAI come in precut forms and cannot be cut or modified at the building site, and also are vulnerable to being punctured by nails or screws, which would reduce their R/inch value by over 80%. Innovative technologies are being sought that would reduce and stop the loss of vacuum and thus keep the R-value per inch intact by repairing or mitigating cuts and punctures during handling, installation, and use.

- **Air leak detection for new and existing building enclosures:** Infiltration diagnostic technologies are used to measure the infiltration of air through the building envelope windows. While infiltration diagnostic technologies do not themselves correct infiltration problems in buildings and thus save energy, they are a valuable tool for characterizing infiltration issues in a given building, and the test results can be used to estimate the energy savings potential of an infiltration remediation effort. Of particular interest are technologies that can reduce variability in test results, reduce the complexity and effort required for medium/large commercial buildings, reduce disruption to building occupants from testing, and/or enable testing of incomplete façades and façade sections during new construction for quality assurance. The diagnostic technology should also be able to locate *and* quantify dispersed leaks in the building envelope accurately and repeatedly (i.e., provide quantitative location and extent of infiltration), require minimal setup and tear-down effort and require no pressure differential, be fast and accurate (> 10,000 sqft per hour at 2mm leak detection accuracy), and be accurate regardless of outdoor weather conditions.

- **Tunable Dynamic/Variable and Directional Materials:** Optical, hygroscopic and insulation materials that can be tuned to allow for selective flow of moisture, air, and heat, as well as dynamically adjusting their properties in anticipation of future environmental variables. E.g., filter, diode, switch, and transformer, such as vapor diodes – tailored permeance vapor retarder technology to separate moisture from interior air within wall assemblies and thermal switches that change from a barrier to a connector over time or with a change in conditions.

- **Advanced Air-Sealing Technologies for Existing Buildings:** Development of advanced air-sealing technologies designed specifically for use in existing buildings to drastically reduce infiltration or exfiltration of air and other flows. A next-generation air-sealing methodology will require new thought processes on how heat, air, and moisture flow are interrelated and how to best regulate them in order to improve overall building-level system performance, as opposed to a more traditional strategy that focuses on component improvements. Most importantly, to be suitable and cost-effective for existing buildings, these technologies should minimize envelope disassembly and installation complexity, and thus, occupant disruption. The proposed technologies must be able to meet or exceed durability (existing or proposed fire, structure, moisture, and acoustic) requirements. They must also have the ability to seal more dispersed and difficult-to-find leaks and help to meet the following cost and performance targets.
  - Performance Target (reduction in air infiltration):
    a. Residential < 1 ACH50 (air changes per hour at 50 Pa of pressure)
    b. Commercial < 0.25 CFM75/ft2 (cubic feet of air per minute per square foot sealed surface area at 75 Pa of pressure)
  - Cost Target:
    - < $0.5/ft2 finished floor

Questions – Contact: Sven Mumme, sven.mumme@ee.doe.gov

b. Transparent Conductive Anodes for Solid-State Lighting

Several energy-conserving technologies of interest to the DOE and the Office of Building Technologies require conductive materials of advanced composition and design that perform multiple functions such as being highly transparent and electrically conductive. One such important example is Organic Light Emitting Diodes (OLEDs) whose operation depends on efficient charge introduction into various photonic layers and whose optical transmission at wavelengths of practical value is simultaneously very high. These seeming contradictory performance requirements are typically satisfied using Transparent Conducting Oxides (TCOs). Indium Tin Oxide (ITO) possessing an In:Sn atomic ratio of about 10:1, is perhaps the most common TCO coating used to manufacture OLED anodes in generic bottom-up deposited layer device designs. This popular choice evolved from the widespread use of ITO in liquid crystal displays, which is an electric field driven device rather than a current injection design such as an OLED. There are many well-documented reasons why ITO is not an ideal anode material for high efficiency OLEDs including inappropriate work function, difficulty in creating desired patterns, stability, bending on flexible substrates, availability of high quality Indium and the need to process at high temperatures limiting the high speed manufacture of integrated ITO substrates. While considerable research towards identification of alternative materials or structures for OLED anodes has been completed to date, there appears to be only limited success. Should an alternative become available that meets or surpasses the price and performance ratio characteristic of ITO, OLED manufacturers would certainly include it in production OLEDs for general illumination and other applications.

Proposals are sought to demonstrate novel and innovative yet practical alternatives to ITO anode materials or designs under this FOA. More fundamental, materials research might include promising chemical alternatives or even physical substitutes to conventional anode placement, orientation or geometry in OLED device architectures. Successful technical approaches to improve the price and performance relationship of OLED anodes may address the complexities of TCO thin film deposition of constituent metal oxides or alternative conductive surfaces that might be especially relevant to flexible or bendable substrates. Proposals may also address improvements transparency of constituent surfaces, index of refraction matching, and improvement of outcoupling efficiency, chemical or physical stability especially at high photon flux levels or elevated temperatures.

Irrespective of the technical approach proposed, all successful proposals must demonstrate that the enabling research completed under this effort will succeed in producing the predicted reduction in technical risk required to move to successive stages of research. The proposed Phase I effort should be designed to retire significant technical risk and make proof of principle of the proposed approach. Phase II may continue to develop the approach towards successful commercial transition but the fundamental question of penultimate price and performance should be well documented and clear in the Phase II proposal. If proven successful, eventual commercial development of the approach might occur after the Phase II period of performance is complete. The primarily benefit of the research supported under this topic must be to the emergent OLED market for general illumination applications but might also demonstrate crosscutting opportunities applicable to other EERE technologies. Moreover, all successful proposal must clearly demonstrate the potential of the subject research to eventually achieve the OLED device price and performance objectives equal to or greater than those specified in the SSL R&D Plan for the year in which commercialization is predicted.

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

c. Whole-Building Energy Modeling

Whole-building energy modeling (BEM), physics-based simulation of building energy use, is a multi-purpose tool for building energy efficiency with traditional applications in architectural design, HVAC system selection and sizing, energy-efficiency code compliance, asset rating, documentation for energy-efficiency green certificates and financial incentives, and stock-level analysis for typical savings calculations; and new applications in control algorithm design, fault detection, model-predictive control, and city-scale analysis. DOE has an established program in the BEM area, with open-source products such as the EnergyPlus BEM engine and the OpenStudio BEM software-development kit and application, along with complementary products like the Radiance detailed lighting engine and the THERM package for detailed envelope simulation.

DOE seeks new BEM applications, services supporting the BEM practitioner community, or innovative enhancements to traditional tools and workflows. An incomplete list of examples include:

- Low-cost model acquisition and refinement for existing buildings using non-traditional data sources.
- Novel model input calibration strategies and approaches.
- Coupling of BEM with other analysis engines.
- New BEM workflows including web-based workflows.
- Applications combining BEM with measured data in novel ways.
- New applications of BEM targeting non-traditional end users such as facility managers.

Use of DOE BEM tools is not required.

Questions – Contact: Amir Roth, amir.roth@ee.doe.gov.

d. TECHNOLOGY TRANSFER OPPORTUNITY: Subwavelength Coatings and Methods for Making and Using Same

Industry seeks advanced optical coatings to selectively block and redirect light. Such coatings enable energy-efficient window films or coatings for buildings, aerospace and vehicles, building envelope materials, display coatings, and tamper-resistant seals. By one estimate, if optical coatings could dynamically and selectively control both visible and infrared light for windows, building owners could save up to 20% in cooling costs and up to 30% in annual heating costs. Some window technologies can dynamically switch between blocking and transmitting light, but these technologies are not well established in the market, are prohibitively expensive to produce, and block both visible and infrared heating, masking the view out the window and preventing natural lighting. In addition, no such optical coatings exist for building envelope applications, displays, or tamper indication uses. PNNL's electrochromic and thermochromic subwavelength coatings can meet these needs. They are expected to be scalable to very large sizes (meters squared) appropriate for buildings and windows in a high-throughput roll-to-roll fashion and can be manufactured at low cost. These coatings have the potential to control ultraviolet, visible, and infrared light.

Licensing Information:
Pacific Northwest National Laboratory:
Contact: Sara Hunt (sara.hunt@pnnl.gov ; 509-375-6555)
License Type: Exclusive
Patent Status: U.S. Patent 9,580,793 Issued February 28, 2017 USPTO
Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=9,580,793.PN.&OS=PN/9,580,793&RS=PN/9,580,793
More info: http://availabletechnologies.pnnl.gov/technology.asp?id=446

For a webinar providing a technology overview and an opportunity to ask questions regarding the technology and/or licensing information, please join us Dec. 5th from 10:00 am – 11:00am pacific time using the link or phone numbers below.

Join from PC, Mac, Linux, iOS or Android: https://zoom.us/j/532970939

Or Telephone:
Dial (for higher quality, dial a number based on your current location):
US: +1 646 876 9923 or +1 669 900 6833 or +1 408 638 0968
Meeting ID: 532 970 939

Questions – Contact: Marc LaFrance, marc.lafrance@ee.doe.gov

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10. FUEL CELLS

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

The Fuel Cell Technologies Office (FCTO)[1] is a key component of the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) portfolio. The central mission of FCTO is to stimulate the U.S. economy and global competitiveness by reducing dependence on foreign oil imports and establishing a domestic power and fuel industry using efficient, reliable clean energy technologies through early stage research and technology development. Fuel cells can address our critical energy challenges in all sectors - commercial, residential, industrial, and transportation."

Fuel cell electric vehicles (FCEVs) using hydrogen can achieve significantly higher efficiencies than combustion engines resulting in overall less energy use. Hydrogen can be produced from diverse domestic resources, such as natural gas, oil, coal, and biomass, as well as from renewables using methods such as direct or indirect water splitting. In addition to transportation applications, hydrogen and fuel cell technologies can also serve stationary applications—i.e. providing responsive back-up power and other electric and fuel distribution services improving energy security and reliability. Thus, fuel cell and hydrogen technologies enable American energy dominance by safely and efficiently harnessing domestic resources.

FCTO addresses key technical challenges for both fuel cells and hydrogen fuels (i.e., hydrogen production, delivery and storage). Light duty FCEVs are an emerging application for fuel cells that has earned substantial commercial and government interest worldwide due to the superior efficiencies, reductions in petroleum consumption, and reductions in criteria pollutants possible with fuel cells. Recent analyses project that, if DOE cost targets for FCEVs are met, U.S. petroleum consumption can be reduced by over one million barrels per day[3]. FCEVs reduce petroleum consumption by about 95% in comparison to conventional light duty vehicles when the hydrogen is produced from natural gas[2]. The areas identified in this topic will enable progress toward commercializing light duty FCEVs.

Grant applications are sought in the following subtopic:

a. Smart Tanks for Hydrogen Storage

Fuel Cell Electric Vehicles (FCEVs) are now commercially available in certain parts of the U.S. and around the world with many of these FCEVs meeting the initial DOE goal of a 300 mile driving range using conventional Type IV polymer lined 700 bar compressed tanks. [1] In addition, there are now approximately 30 retail hydrogen refueling stations open to the public in California with several more expected to come online soon. [2] However, growth in the FCEV market beyond early adaptors will require significant reductions in the cost of hydrogen fueling. Hydrogen refueling stations face key challenges relating to capital and maintenance costs as well as station reliability. About 15% of the cost of fueling stations is due to pre-cooling equipment that chills the hydrogen to -40°C [3], such that fills can be completed in three minutes, in compliance with the SAE J2601 Fueling Protocol for Light-Duty Gaseous Hydrogen Surface Vehicles. [4] Pre-cooling to these temperatures also increases performance requirements of hydrogen dispensers, which account for 14% of station cost [3] and are the second largest cause of station maintenance [5]. The requirement to pre-cool hydrogen gas to -40°C is driven by the need to offset the temperature rise caused by the heat of compression during fueling. This requirement is driven by the upper temperature limits (~85°C) of the polymer liner of conventional 700 bar compressed tanks.

Applications are sought for the development of a smart hydrogen storage tank that can reduce or even eliminate the burden of precooling at the hydrogen refueling station without significantly impacting the performance of the hydrogen storage system. Such a design could be applicable to compressed national gas (CNG) tanks and other pressurized gas systems as well. A proposed smart tank must provide a means to efficiently dissipate/absorb or provide a cooling design to offset the heat of compression generated during a three to five minute refuel in order to reduce the required station precooling from -40°C (T40) to at least -20°C (T20). Preference will be given to designs that can further reduce (beyond T20) or even eliminate the need for precooling altogether. Smart tank designs must also take into account adverse effects on hydrogen storage system performance such as added cost, weight, volume, fill time, and impact on well-to-powerplant efficiency. Given the relationship between pressure and temperature, consideration should also be given to obtaining a consistent state of charge regardless of initial state of charge or ambient temperature conditions. Applicants should not only explain how the smart tank design will effectively tackle the heat of compression issue, but also provide preliminary comparisons of their proposed smart tank designs against the DOE baseline 700 bar system which is detailed in the 2015 DOE Hydrogen and Fuel Cells Program Record #15013 "Onboard Type IV Compressed Hydrogen Storage System – Cost and Performance Status 2015". [6] Applicants must also ensure any designs don't negatively impact safety as required by applicable standards for vehicular fuel systems including but not limited to SAE J2579 and the United Nations Global Technical Regulation No.13 (Hydrogen and fuel cell vehicles).

Phase I of this effort is expected to include an in-depth analysis that includes preliminary smart tank design as well as specific research, development, and proof-of-concept component testing of any new components to show they meet any necessary heat dissipation, heat absorption, cooling, or other mechanisms required by the smart tank design to enable the reduction or elimination of the precooling requirements at the station.

Phase II of the effort should focus on the complete smart tank prototype development and testing at a relevant scale (scale that provides confidence that it can be scaled to full size is preferable).

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

b. Materials and Components for High-Pressure Hydrogen Gas Service

Cost-competitive manufacturing of components used in equipment for high-pressure hydrogen gas service requires engineering expertise and advanced steel alloys. Materials are selected based on their compatibility with hydrogen (i.e. tolerance of hydrogen induced damage), ability to withstand mechanical loading (e.g. fatigue cycling at low load ratios), and ability to tolerate extreme pressures and temperatures. Many of the components used at hydrogen fueling stations, as an example, are subject to pressures up to 875 bar and temperatures from -40°C to 85°C. These components are currently only manufactured by a small number of companies, and are often not standardized or manufactured in the U.S. The limited supply chain is consistently identified by stakeholders as a driver of high costs and long lead times of hydrogen equipment. [1, 2] Moreover, while U.S. companies have potential to secure a competitive edge in the area of hydrogen equipment (due to proximity to end users and available expertise) [3], their limited access to the supply chain for individual components may restrict equipment manufacturers from expanding horizontally into hydrogen.

Applications are sought for the development of cost-competitive fittings / components used in high-pressure ($\geq$ 875 bar) hydrogen service applications, with preference given to components manufactured using novel / low cost manufacturing techniques. Fittings of interest include dispensing nozzles, breakaway couplings, end connectors, and valves for both compression and dispensing. Examples of costs of common fittings in hydrogen service are provided in. [3] Applicants should define the target application of the fittings proposed, and the service conditions (e.g. pressure, temperature, cycle frequency and load ratio). Proposed technologies should be scalable for high-volume manufacturing.

Phase I applications should include either:

- Development of materials that will be incorporated into specific components, and coupon testing of those materials, or:
- Development of robust computational models / design of a manufacturing approach to developing full components.

Phase II applications should involve use of the manufacturing approach or material developed in Phase I to develop components, and testing of those components. Testing will aim to evaluate components' compliance with the performance requirements of relevant codes and standards (e.g. ASME, CSA, ASTM), and may include fatigue life, burst strength, and/or off-gassing.

Questions – Contact: Nancy Garland, nancy.garland@ee.doe.gov

c. Non-destructive Evaluation Technologies for Steels

Limitations in the sensitivity of non-destructive evaluation (NDE) technologies for steel challenge component development and maintenance in many sectors, including pressure vessels used in hydrogen service, nuclear reactors [1], and oil and gas production and refining. Technologies commonly used to detect flaws in vessels and pipelines include ultrasonic testing, x-ray imaging, electro-magnetic acoustic transducers, and radiography. [2, 3] Disadvantages of these technologies include their sensitivity to microstructural flaws (particularly when used in-field), and the robustness and ease-of-use of models that subsequently predict macrostructural damage based on measurements of flaw size. Improvements in flaw detection in service environments can lower the costs of equipment maintenance, particularly for equipment that is difficult to access (e.g. underground hydrogen storage vessels). Hydrogen storage vessels currently account for about 14% of the cost of fueling stations [3], and stakeholder engagement (e.g. through Requests for Information) has indicated significant interest in underground storage vessels. Underground storage vessels have potential to lower the footprint of fueling stations, which is also of significant interest to stakeholders. [4] Additionally, improvements in NDE of raw materials can lead to improved predictions of equipment service life, therein allowing for the use of materials or designs that are otherwise assumed to be unsuitable.

Applications are sought for the development of new detection methods, and/or the development of data processing packages that can predict remaining design life on the basis of microstructural flaws. Applicants should define the intended application of the technology being developed. Technologies developed should be capable of detecting flaws in three dimensions, at lengths of 10s of microns. Technologies developed should also be capable of tolerating the conditions of the intended service application (e.g. 400 bar pressures for underground hydrogen storage vessels), should operate at speeds that are appropriate for the intended application, and should be user-friendly enough for in-field use. Data processing packages developed should be capable of predicting millimeter-scale damage based on micron-level flaws, and should be verified with experimentation on multiple microstructures of steel.

Phase I may include:

- Evaluation of NDE technologies currently available for application of choice, and down-select of technologies to focus on for enhancement of sensitivity. After down-select, specific modifications that should be made to enhance accuracy are defined.
- Preliminary experimental work to establish viability of a new approach to NDE.
- Initial computational modeling to correlate microstructural flaws to macrostructural damage.

Phase II may include:

- Creation and experimental verification of a prototype NDE device
- Creation and experimental verification of a user-friendly data processing package for integration into an NDE device.

Questions – Contact: Neha Rustagi, neha.rustagi@ee.doe.gov

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11. GEOTHERMAL

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

Heat energy from the earth represents a nearly inexhaustible and underutilized domestic energy resource. The Office of Energy Efficiency and Renewable Energy's Geothermal Technologies Office (GTO) (www1.eere.energy.gov/geothermal/) works in partnership with industry, academia, and DOE's National Laboratories to improve the competitiveness of geothermal power as a baseload, dispatchable, domestic energy supply. Currently, the U.S. has nearly 3.6 gigawatts electric (GWe) of installed geothermal capacity, while new technologies such as Enhanced Geothermal Systems (EGS) could enable access to than 100 GWe of new geothermal capacity. In addition, U.S. Geological Survey estimates the potential beneficial direct use of heat from low-temperature (<90 °C) geothermal resources to be 46.5 gigawatts thermal (GWth). Consistent with the administration's R&D priorities in American Energy Dominance, developing additional domestic geothermal energy resources will help provide a reliable, long-term supply of low cost energy, enhance security through energy independence and create a stable supply of high-paying jobs. Development of domestic geothermal energy sources should be an integral part of our nation's future clean energy portfolio.

One of the areas GTO is interested in is the direct use applications of geothermal heat such as district heating and cooling, residential and commercial applications, industrial processes, and agricultural uses. Since lower temperature heat sources generate electricity less efficiently, direct use applications are an attractive alternative for low temperature geothermal resources (<90 °C). These resources can come from lower temperature geothermal reservoirs or from cascaded applications from higher temperature geothermal resources. One such direct use application is to use the heat from a geothermal resource to treat water through an innovative thermally-driven forward osmosis process.

Geothermal energy has the benefit of being a reliable "always-on" electricity source. According to EIA data, geothermal annual capacity factor is the second highest of all utility scale generation technologies, with only nuclear power being higher. To become more valuable as the amount of intermittent electricity sources and demand response increases throughout the nation, the geothermal industry is exploring the possibility of providing electricity on demand. Turning baseload geothermal generation into a dispatchable electricity source would come at the cost of curtailment and possible adverse long term effects on the geothermal reservoir, but the benefit of providing the ancillary services to the grid may outweigh these costs. Flexible geothermal can provide value to utilities in avoided costs such as integration, transmission, gas transportation, and storage costs. Operating as a dispatchable source is especially attractive given the fact that geothermal can produce electricity without incurring additional fuel costs. There is a current example of flexible geothermal operation at the Puna Geothermal Venture in Hawaii; however, there remains open questions on the lifecycle costs of flexible geothermal operation.

Grant applications are sought in the following subtopics:

a. TECHNOLOGY TRANSFER OPPORTUNITY: Low Enthalpy Geothermal Forward Osmosis

The Geothermal Technologies Office seeks to partner with a small business to commercialize a novel Forward Osmosis (FO) process driven by low-enthalpy geothermal heat. In contrast to Reverse Osmosis (RO), which utilizes mechanical energy to create a pressure gradient across a membrane to purify water, FO can be achieved by utilizing a draw solution to create an osmotic pressure gradient across the membrane to treat the water. Historically, FO systems have had limited utility because draw solutes have been difficult to separate from the treated water. Researchers at Idaho National Laboratory (INL) have developed a system for implementing FO using a switchable-polarity solvent (SPS) draw solution that can be easily extracted from the treated water stream and reused.

The Switchable Polarity Solvent Forward Osmosis (SPS-FO) process can purify water from extremely concentrated feeds containing salts, organics, inorganics, and biologics and has been demonstrated to:

- provide osmotic flux against a 226,000 ppm total dissolved solids (TDS) NaCl solution with a potential to treat higher concentration solutions;
- increase the water extraction compared to RO systems, leaving a smaller volume of highly concentrated brine discharge; and
- reduce membrane fouling issues and pretreatment requirements when compared to RO systems.

INL assesses the SPS-FO process to be at Technology Readiness Level (TRL) 3 – a proof of principle has been tested and validated at an integrated bench scale for an SPS-FO system with 1-Cyclohexylpiperidine working fluid and a commercially available forward osmosis membrane. The process is designed to be driven by small amounts of low grade heat (70 °C) and can scale from container sized systems producing 10,000 gallons per day to millions of gallons per day plant operations. SPS-FO can be combined with other existing water treatment technologies to treat a variety of feed streams.

The market application of this technology is flexible for this subtopic; however, the primary heat energy to drive the system must come from a geothermal source. Some potential markets applications can include, reducing the volume of produced waters in need of disposal from oil and gas operations; concentrating geothermal brines for the purpose of enhancing mineral recovery; or treating water for use at a geothermal power plant such as blow-down water for evaporative cooled systems.

To be economical this process would likely need to make use of a readily-available geothermal heat source that would otherwise be rejected (e.g. as a bottoming cycle on current geothermal operations or using low-grade heat from oil and gas produced waters). Applications that show the greatest potential to increase the beneficial use of domestic geothermal energy resources will be considered more favorably.

Licensing Information:
Idaho National Laboratory Information
Contact: Ryan Bills (ryan.bills@inl.gov ; 208-526-1896)
License type: Non-exclusive
Patent Status:

- US Patent Application No. 13/480,053, BEA Docket No. BA-583: "Methods and Systems for Treating Liquids Using Switchable Solvents," filed 24 May 2012
- US Patent No. 9,399,194, BEA Docket No. BA-808: "Methods for Treating a Liquid Using draw Solutions," issued 26 July 2016
- U.S. Patent Pending - Application No. 15/177,528, BEA Docket No. BA-870: "Methods and Systems for Treating a Switchable Polarity Material, and Related Methods of Liquid Treatment," filed 9 June 2016.

Questions – Contact: Josh Mengers, joshua.mengers@ee.doe.gov

b. Dispatchable Geothermal Operations

The Geothermal Technologies Office solicits innovations that will enable geothermal energy to be more widely deployed as a dispatchable electricity source. These innovations can be in developing new hardware solutions, new systems of existing technologies, or new control algorithms and/or processes. Some potential areas of interest include: offsetting parasitic loads from normal plant operations during curtailment, improving lifetime reservoir performance, and integrating novel storage technology. The innovation could also take the form of developing an analysis tool that provides a valuation of operating current geothermal power plants in a flexible mode; however, any application proposing such an analysis tool must clearly show the ability to monetize their innovation in the commercialization plan.

Essential scope for any successful phase I award is a full techno-economic analysis (TEA) of the proposed innovation that accounts for the costs of curtailment, parasitic loads, storage, and lifetime resource temperature decline. The TEA must provide realistic assumptions about how utilities will compensate the ancillary services provided. In order for the award to continue into Phase II, the TEA from Phase I must clearly show that dispatchable geothermal will provide significant value to the grid and demonstrate a clear pathway for the geothermal plant developers/operators to monetize that value.

Based upon the recommendations from the California Energy Commission's workshop on flexible geothermal (Ref 8.), applications to this subtopic that will enable new development of flexible flash or steam geothermal plants will be given preference over innovations for existing plants or binary / combined cycle geothermal plants. To be responsive to this subtopic, the applicant must clearly describe in the letter of intent and application how the primary goal of the proposed project is to enable geothermal energy to be more widely deployed as a dispatchable electricity source.

Questions – Contact: Josh Mengers, joshua.mengers@ee.doe.gov.

References:

1. Williams, C. F., DeAngelo, J. and Reed, M. J., 2015, Revisiting the Assessment of Geothermal Resources <90 °C in the United States., GRC Transactions, Volume 39, p. 93-98. http://pubs.geothermal-library.org/lib/grc/1032137.pdf

2. U. S. Energy Information Administration, 2017, Electric Power Monthly with Data for June 2017, U. S. Department of Energy, p. 246. https://www.eia.gov/electricity/monthly/pdf/epm.pdf

References: Subtopic a:

1. Stone, M. L., Rae, C., Stewart, F. F., et al, 2013, Switchable Polarity Solvents as Draw Solutes for Forward Osmosis, Desalination, Volume 312, p. 124-129. http://www.sciencedirect.com/science/article/pii/S0011916412004055

2. Orme, C. J. and Wilson, A. D., 2015, 1-Cyclohexylpiperidine as a Thermolytic Draw Solute for Osmotically Driven Membrane Processes, Desalination, Volume 371, p. 126-133. http://www.sciencedirect.com/science/article/pii/S0011916415003458

3. Wendt, D.S., Orme, C. J., Mines, G. L., et al, 2015, Energy Requirements of the Switchable Polarity Solvent Forward Osmosis (SPS-FO) Water Purification Process, Desalination, Volume 374, p. 81–91. http://www.sciencedirect.com/science/article/pii/S0011916415300205

4. Wendt, D.S., Adhikari, B., Orme, C. J., et al, 2016, Produced Water Treatment Using the Switchable Polarity Solvent Forward Osmosis (SPS FO) Desalination Process: Preliminary Engineering Design Basis, GRC Transactions, Volume 40, p. 1-26. https://www.osti.gov/scitech/servlets/purl/1367836

5. Adhikari, B., Jones, M. G., Orme, C. J., et al, 2017, Compatibility Study of Nanofiltration and Reverse Osmosis Membranes with 1-cyclohexylpiperidenium Bicarbonate Solutions, Journal of Membrane Science, Volume 527, p. 228-235. http://www.sciencedirect.com/science/article/pii/S037673881632230X

References: Subtopic b:

1. California Energy Commision, 2016, Proceedings from the California Energy Commission's Pre-Solicitation Workshop on Identifying Research Priorities on Flexibility and Other Operational Needs for Existing Geothermal Power Plants. (Written comments by Josh Nordquist, Ormat NV Inc., are particularly noteworthy.) http://www.energy.ca.gov/research/notices/2016-01-28_workshop/.

12. SOLAR

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

The Solar Energy Technologies Office (SETO) is a technology-focused organization established within the Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE). Its mission is to support the development and application of technology to promote the widespread adoption of solar power in the USA. This mission is executed through the efforts of tailored programs that collectively form the SunShot Initiative (http://energy.gov/eere/sunshot/sunshot-initiative). SETO launched the SunShot Initiative in August 2010 with the goal of solar electricity becoming price-competitive with conventional utility sources by 2020. This goal has already been achieved for utility-scale photovoltaics, and with continued effort, it is likely to be achieved for all solar applications. SunShot additionally set a 2030 goal (https://energy.gov/eere/sunshot/sunshot-2030) to further reduce the cost of solar electricity by half, which would enable solar to cost-effectively supply a substantial fraction of U.S. electricity demand.

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

- Propose a tightly structured program which includes technical and business 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.

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

a. TECHNOLOGY TRANSFER OPPORTUNITY: Devices and Methods for De-Energizing a Photovoltaic System

The 2017 changes to §690.12 of the National Electrical Code [1] require that all photovoltaic systems installed in or on buildings include a 'rapid shutdown' mechanism which reduces the voltage within 1 inch of an installed module to less than 80V within 30 seconds of rapid shutdown initiation. While this requirement is currently challenging to achieve in a cost-effective manner, NREL has developed a prototype analog device which quickly and reliably de-energizes photovoltaic modules in compliance with §690.12 and is projected to cost on the order of $0.01/Watt_{DC}$ to install. We are looking for partners to scale this prototype to larger system voltages and to subsequently commercialize and deliver products to interested parties in order to simplify compliance with the 2017 NEC.

Licensing Information:

National Renewable Energy Laboratory Information
Contact: Bill Hadley; bill.hadley@nrel.gov ; (303) 275 3015
License type: Exclusive
Patent Status: Application Serial No. PCT/US16/50927
Publication date: Mar 23, 2017
Filing date: Sep 9, 2016

Additional information: https://techportal.eere.energy.gov/technology.do/techID=1285

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

b. Cybersecurity for Solar Energy Devices

Advanced cybersecurity may be needed to ensure access-control, authorization, authentication, confidentiality, integrity, availability, and non-repudiation for the future smart grid. In this subtopic SunShot is soliciting research ideas for new hardware and/or software solutions that can improve the cybersecurity of electronic devices associated with the generation of solar energy such as, but not limited to, inverters, DC-DC Optimizers, smart meters, etc. Proposed solutions should discuss the component(s) being addressed, potential threats that will be deterred, method of integration (especially clarifying if it is part of a traditional PV component for integration at install or a retrofit for a fielded device), how interoperability with other components is considered and how compromises or attempted compromises are conveyed to the relevant parties. Proposed solutions should not be limited to conventional cybersecurity techniques. Proposing companies are encouraged to think outside the box.

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

c. Peer-to-peer Energy Transactions

We are soliciting research ideas aimed at decreasing the levelized cost of solar electricity and increasing the value of distributed generation for individual consumer. Fast growing residential PV solar installations, which accounted for about 40% of the total U.S. solar energy production in 2016, have led to the rise of individual energy "prosumers" – those connected to the grid both producing and consuming electricity. Peer-to-peer energy transaction technologies allow participants (e.g., individual residences, commercial operators, distributed energy resource "DER" aggregators, or utilities) in the network to transact directly with every other network participant without involving a third-party intermediary [1]. Because of its focus on the "prosumers" rather than on the utilities, the primary application of this research is behind the meter.

This subtopic is focused on research to enable distributed peer-to-peer ledgers for operating and managing electric power distribution networks with significant DER loading. Research to date in this area has not addressed scalability of the technology, need to reduce interconnection and transaction time; enabling of load shifting, cybersecurity and most importantly has failed to produce technologies – such as *standardized smart contracts, interoperability between different ledgers, and integration with power management systems* that could dramatically reduce transaction costs [2].

Proposed research topics should include methods to efficiently track transactions and compensate users, and that can be incorporated into existing utility infrastructure and community energy systems. We will consider both software-only solutions and applications that control the real-time flow of power. Solutions should address the following issues:

- scalability of the technology;
- transparency of the energy transaction process;
- decreased interconnection and transaction time compared to current state of the industry;
- load shifting enabled through local/distributed power purchasing;
- cybersecurity capabilities;
- strong market analysis;

- reduction in transaction costs (possibly <0.1 ¢/kWh);
- viable commercialization plan.

Research proposals should also include a plan to engage with distribution system operators of electric power distribution networks to accommodate transactive energy markets. Also, the application should include a description of which existing technologies, platforms, architectures will be leveraged for the project and the novelty of the proposed solution compared to the state of the art.

In addition, use of smart contracts and decentralized ledgers for local systems that are still connected to the grid should consider methods to maximize the economic and technological benefits related to local short-term solar forecasting and dynamic pricing technologies.

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

d. Research in autonomous and augmented systems to reduce solar LCOE

SETO seeks to fund research into the use of automation and augmentation technologies for solar system hardware installation that could significantly reduce solar LCOE [1]. Research in this area is encouraged in order to explore the potential solution space for use in solar energy. The unstructured, complex environment of typical solar energy sites (i.e. terrain, dusty conditions, and weather patterns) has prevented the use of automated or human-augmented technologies and approaches, resulting in a reliance on primarily manual processes. Research to explore novel and innovative approaches is necessary to encourage new ways of solving old and persistent challenges. Exploration under this topic would show a step change in the time and complexity compared to the state of the art in photovoltaics [2] and concentrating solar power [3]. Research proposals of interest will address the following items:

- Utilization of automation technologies for maximum impact on levelized cost of electricity (LCOE);
- Significant potential to decrease installation cost: $/W;
- Significant potential to decrease required installation time compared to the current state of the art: min/W;
- Evaluation of the state of technologies required by the solution;
- Comparison of predicted costs with costs of traditional installation techniques.

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

References: Subtopic a:

1. Explore the 2017 NEC, National Fire Protection Association. http://www.nfpa.org/nec/about-the-nec/explore-the-2017-nec

References: Subtopic c:

1. Barbose, G., Miller, J., Sigrin, B., et al, 2016, On the Path to SunShot: Utility Regulatory and Business Model Reforms for Addressing the Financial Impacts of Distributed Solar on Utilities, National Renewable Energy Laboratory, p. 82. https://www.nrel.gov/docs/fy16osti/65670.pdf

2. Jin, X. and Meintz, A., 2015, Challenges and Opportunities for Transactive Control of Electric Vehicle Supply Equipment: A Reference Guide, National Renewable Energy Laboratory, p. 30. https://www.nrel.gov/docs/fy15osti/64007.pdf

References: Subtopic d:

1. Woodhouse, M., Jones-Albertus, R., Feldman, D., et al, 2016, On the Path to SunShot: The Role of Advancements in Solar Photovoltaic Efficiency, Reliability, and Costs, National Renewable Energy Laboratory, p. 43. http://www.nrel.gov/docs/fy16osti/65872.pdf

2. Mehos, M., Turchi, C., Jorgenson, J., et al, 2016, On the Path to SunShot, Advancing Concentrating Solar Power Technology, Performance, and Dispatchability, National Renewable Energy Laboratory, p. 51. http://www.nrel.gov/docs/fy16osti/65688.pdf

3. Jones-Albertus, R., Feldman, D., Fu, R., et al, 2016, Technology Advances Needed for Photovoltaics to Achieve Widespread Grid Price Parity, Progress in Photovoltaics: Research and Applications, p. 12. https://energy.gov/eere/sunshot/downloads/technology-advances-needed-photovoltaics-achieve-widespread-grid-price-parity

13. VEHICLES

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

EERE's Vehicle Technologies Office (VTO) (https://energy.gov/eere/vehicles/vehicle-technologies-office) 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. Since 2008, the Department of Energy has reduced the costs of producing electric vehicle batteries by more than 50%. DOE has also pioneered improved combustion engines that have saved billions of gallons of petroleum fuel, while making diesel vehicles as clean as gasoline-fueled vehicles. Continued support in these areas not only improves our nation's fleet of vehicles, but ensures American prosperity (subtopics A, B, and C), energy dominance (subtopic A) and military superiority (subtopic A and B). It does this by encouraging R&D that will sustain America's economic prowess and growth while supporting job creation in emerging technologies such as autonomous systems, machine learning, and energy storage; developing technologies with dual-use potential that can support the military of the future; and providing energy storage technologies for lower-cost domestic renewable energy technologies.

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.

Applications may be submitted to any one of the subtopics listed below 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. Multi-Year Program Plan (MYPP) or Roadmap 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. Electric Drive Vehicle Batteries

Applications are sought to develop electrochemical energy storage technologies that support commercialization of micro, mild, and full HEVs, PHEVs, and EVs. Some specific improvements of interest include the following: new low-cost materials; high voltage and high temperature non-carbonate electrolytes; improvements in manufacturing processes – specifically the production of mixed metal oxide cathode materials through the elimination or optimization of the calcination step to reduce cost and improve throughput, 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. Applications deemed to be duplicative of research that is already in progress or similar to applications already reviewed this year will not be funded; therefore, all submissions should clearly explain how the proposed work differs from other work in the field.

Questions – Contact: Samm Gillard, Samuel.gillard@ee.doe.gov

b. Exploratory Low Cost Motor Designs for Electric Drive Vehicles

Electric Drive Technologies R&D within the Vehicle Technologies Office has a goal to decrease electric motors' cost, volume, and weight while maintaining or increasing performance, efficiency, and reliability. To achieve these goals, VTO and its partners are already examining many research avenues, including: lower-cost permanent magnets and magnetic materials; reduced rare-earth magnet motors; non-permanent magnet motor designs; and improving electric motor thermal management, performance and reliability. Many of these approaches and their benefits are described in the U.S. DRIVE partnership Electrical and Electronics Technical Team Roadmap.

This topic seeks to address the challenge of lower cost motors for vehicle traction through the development of exploratory motor designs that can significantly reduce the cost of materials used in motors that are suitable for vehicle propulsion. Applications should describe approaches to motors that can significantly reduce material costs and do not require any materials that contain rare earth elements. Motor costs should strive to achieve 2025 VTO Electric Drive System targets [2] with 55% of system costs allocated to the motor. These motor designs should differ significantly from current or previous DOE research projects, and performance claims or benefits need to be supported by sufficient mathematical modeling and data analysis. Applicants should show a relationship to, and demonstrate and understanding of, automotive application requirements and environments. Proposals should also describe a cost model comparing the proposed motor design to a baseline automotive traction motor. Projects should aim to design and simulate a full 100 kW peak capable motor in Phase I, with plans to prototype at least one motor in Phase II.

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

c. Research on Energy Efficiency in Emerging Mobility Systems

The U.S. transportation system is poised for dramatic change over the next decade, driven by technology, demographic, and societal trends. This transformation is already underway: transportation network companies currently offer ride-hailing, ride-sharing, and car-sharing services in most major urban areas, and vehicle manufacturers are developing new connected and automated vehicle technologies expected to be commercialized in the near term. This transition has the potential to significantly affect transportation energy consumption for both passengers and freight, though the direction and magnitude of this impact is highly uncertain [1]. These system-level mobility solutions may be among the most advanced, cost-effective technologies to improve the energy efficiency and environmental performance of vehicles as the transportation system evolves.

VTO's Energy Efficient Mobility Systems (EEMS) Program aims to forge a maximum-mobility, minimum-energy future by understanding the significant energy impacts that may result from the coming mobility transformation, and conducting research to identify and develop the most promising technologies to reduce the energy used in transporting people and goods. By discovering the energy opportunities enabled by emerging technologies such as connected and automated systems, machine learning, and high-performance computing, VTO supports innovative mobility solutions that lead to economic growth and prosperity [2]. The EEMS Program conducts transformative energy research not considered by the private sector, to unlock enormous economic value and improve the affordability of and accessibility to transportation for all Americans [3]. Different EEMS technology pathways could lead to widely varying non-additive fuel saving benefits, especially with increased adoption of advanced powertrain vehicles (e.g., hybrid electric and plug-in battery electric vehicles). Therefore, an important federal role exists in encouraging new mobility research that maximizes public benefits.

Applications are sought to develop novel solutions and technologies that enable energy efficiency improvements in personal and freight mobility by addressing key knowledge gaps related to connectivity, automation, and machine-learning applications for on-road transportation. Potential solutions should support a pathway to 50% transportation system-wide energy reduction, while maintaining or improving access to mobility, and may include, but are not limited to, the following:

- Hardware technologies such as:
- Advanced devices, sensors, and components that use connectivity and automation to significantly reduce vehicle- and transportation system-level fuel consumption without negatively impacting mobility.
- Personal mobility concepts that incorporate novel materials and/or powertrain designs, compatible with a future automated, connected, and shared transportation scenario, that result in transportation energy savings and mobility system improvements.

- Non-hardware solutions such as:

- Software and control algorithms that use real-time data to optimize vehicle or traffic behavior to achieve energy reductions and mobility enhancements.
- Computational methods that incorporate artificial intelligence or machine learning to identify and leverage energy reduction opportunities in the transportation network while improving mobility access.

Applications must quantify the expected energy savings and mobility impacts that directly result from the proposed technology. Applications deemed to be duplicative of research that is already in progress or similar to applications already reviewed this year will not be funded; therefore, all submissions should clearly explain how the proposed work differs from other work in the field.

Questions – Contact: David Anderson, david.anderson@ee.doe.gov.

References: Subtopic a:

1. U.S. Council for Automotive Research, Energy Storage System Goals. www.uscar.org/guest/article_view.php?articles_id=85.

2. U.S. Council for Automotive Research, USABC Manuals. www.uscar.org/guest/article_view.php?articles_id=86.

3. U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (DRIVE), 2013, Electrical and Electronics Technical Team Roadmap, U.S. Department of Energy, p. 24. https://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/eett_roadmap_june2013.pdf

References: Subtopic b:

1. U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (DRIVE), 2013, Electrical and Electronics Technical Team Roadmap, U.S. Department of Energy, p. 24. https://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/eett_roadmap_june2013.pdf

2. Vehicle Technologies Office, 2017, Electric Drive Technologies, Grid, and Infrastructure, U.S. Department of Energy, p. 22. https://energy.gov/sites/prod/files/2017/06/f34/edt000_boyd_2017_o.pdf

References: Subtopic c:

1. Stephens, T. S., Gonder, J., Chen, Y., et al, 2016, Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles, National Renewable Energy Laboratory, p. 48. https://www.nrel.gov/docs/fy17osti/67216.pdf

2. U.S. Office of Management and Budget, 2017, The Annual Memorandum on Administration Research and Development Budget Priorities from the head of the OMB and the Office of Science and Technology Policy. https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2017/m-17-30.pdf

3. Office of Energy Efficiency and Renewable Energy, 2017, The Transforming Mobility Ecosystem: Enabling an Energy Efficient Future, U.S. Department of Energy, p. 30. https://energy.gov/eere/vehicles/downloads/transforming-mobility-ecosystem-report

14. WIND

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

The Office of Energy Efficiency and Renewable Energy's Wind Energy Technologies Office (https://energy.gov/eere/wind/wind-energy-technologies-office), seeks applications for innovations that significantly reduce the cost of energy from U.S. wind power resources for land-based, offshore and distributed wind turbines. The Wind Energy Technologies Office (WETO) is seeking proposals for technology innovations with the potential to enable wind power to generate electricity offshore and in all 50 states cost competitively with other sources of generation.

Today, wind energy provides nearly 6% of the nation's total electricity generation. At the end of 2016, over 77,000 wind turbines, totaling 992 megawatts (MW) in cumulative capacity, were deployed in distributed applications across all 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. Additionally, 82 gigawatts (GW) of utility-scale wind turbines are installed across 41 states plus Puerto Rico and Guam. Finally, one of the smallest states in terms of both geographic size and installed wind capacity marked a major milestone in 2016, as the nation's first offshore wind project, the 30 MW Block Island project in Rhode Island, achieved commercial operation. With wind power generation exceeding 10% in 14 of those states, wind is a demonstrated clean, affordable electricity resource for the nation.

WETO aims to accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality. Advancing WETO Research, Development, Demonstration and Deployment (RDD&D) activities are applicable to utility-scale land and offshore wind markets, as well as distributed turbines—typically interconnected on the distribution grid at or near the point of end-use. Achieving LCOE goals will support deployment of wind at high penetration levels, sufficient to meet up to 20% of projected U.S. electricity demand in 2030, and up to 35% in 2050, compared to over 5.5% of demand in 2016. DOE plays a unique and valuable role in enabling the wind industry and its stakeholders to meet core challenges to industry growth through innovation to reduce wind technology costs and mitigate market barriers enables deployment and drives U.S. economic growth.

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. Vision or Roadmap 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 and; justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Innovations in Distributed Wind System Design

Cost reductions, more reliable technology, and consumer friendly business models are making distributed generation (DG) technologies (e.g. solar, storage, wind) more accessible to residential, commercial, and industrial power customers interested in self-generating their power requirements. To remain competitive in this expanding global market, U.S. manufacturers of small and medium size wind turbine technology must optimize their designs for distributed applications and reduce total installed costs. Over the past 10 years, the majority of public and private sector funding for wind turbine research and development (R&D) has gone towards creating larger and larger wind turbine designs for utility-scale applications, and reducing balance of plant costs through standardization. Many of the learnings from these R&D investments can be leveraged to help U.S. manufacturers develop next generation small and medium scale wind turbine technology for distributed applications, and support the development of standardized components, such as inverters, towers and foundations, for balance of plant and soft cost reductions.

- **Distributed Wind Substructure and Balance of System Cost Reduction:** Balance of system components (e.g. towers, foundations, inverters) for distributed wind systems—particularly for small turbines under 100kW—can account for well over 50% of total installed costs. [1, 2] Moving from one-off designs for these components to standardized design solutions that apply across a wide range of turbine types and sites has the potential to significantly reduce these costs. Rather than one-off designs that are optimized for a particular system and location, DOE is seeking applicants to develop tower, substructure or other balance of system component design solution(s) that represent the most cost-effective compromise across a broad range of applications for mass production. Close coordination between distributed wind turbine original equipment manufacturers (OEMs) and balance of plant component supply chain vendors will be required. Applicants will be expected to specify areas of technology development as well as provide commitments from OEMs willing to participate. Applicants should describe a detailed approach for achieving component standardization that leads to high volume component purchasing, thereby reducing costs and lowering LCOE for a specified size range of wind turbine designs. Work under this topic area should address designs for substructure and balance of system components that can apply across a wide range of turbine and site types for a given turbine size class (e.g. 10-20 kW), including standardized interfaces between these and other components to ensure wide compatibility across turbine, tower and other component manufacturers.

- **Advanced, innovative manufacturing technologies**: Currently, Wind turbine components are manufactured in batch processes, rather than the continuous "assembly line" processes of most other consumer and commercial capital goods. As current fabrication processes can be costly and time intensive, new advanced manufacturing technologies and processes hold promise for lowering the cost of small and medium wind systems. Recent Advancements in composite materials, automation, and more efficient manufacturing processes have helped domestic manufacturers dramatically increase productivity throughout the past decade. DOE is seeking applicants to expand upon these practices, and improve upon or develop innovative advanced manufacturing techniques which would reduce production time and cost, without sacrificing quality or reliability of wind turbine components. [1,2]

Questions – Contact: Michael Derby, michael.derby@ee.doe.gov.

b. Innovations in Utility-Scale Performance (1MW or larger)

Currently, 41 of the states in the U.S. have deployed utility-scale wind. WETO's programmatic goals are to reduce the unsubsidized market LCOE for utility-scale land based wind energy systems from a reference wind cost of 5.6 ¢/kWh in 2015 to 5.2 ¢/kWh by 2020 and 3.1 ¢/kWh by 2030. WETO R&D has resulted in significant U.S. wind industry innovation and cost reduction. The research, development and demonstration of innovative turbine technology on the MW-scale that has been funded by WETO has enabled cost-competitive utility-scale wind. With untapped utility-scale land based and offshore wind markets in all 50 states, the office invests in early stage applied energy science research, development, and validation activities for utility scale wind.

- **Advanced Manufacturing for OffShore Wind Foundations:** Offshore wind foundation technology is largely derived from offshore oil and gas experience. While the engineering principles for offshore oil and gas foundation technologies are appropriate for offshore wind development, oil and gas platforms are manufactured on a one-off basis. In order to reduce the cost of offshore wind, serial production must be employed for the fabrication of foundations. DOE is seeking advanced manufacturing technologies and processes in order to facilitate assembly-line production methodologies of offshore foundations for fixed bottom or floating applications in order for offshore wind to compete without subsidy. Applicants must propose specific advanced manufacturing options that could enable a more rapid production of offshore wind foundations, driving down the cost of offshore wind energy, including automation, advanced materials, advanced protective coating technology, etc. Further, demonstrating how these methodologies could be deployed in ports along the East Coast, where current offshore wind demand exists and where lay-down space may be limited, would be of interest. [1,2]

- **Mooring Systems Innovation and technologies for Offshore Floating Installations:** Based on industry feedback, the Wind Energy Technologies Office has found that the mooring schemes for floating offshore wind platforms are extremely technologically challenging in water over 1,000 m deep, resulting in a mooring system that is not economical. In the United States, there is approximately 10,800 GW of offshore wind gross potential, and over 60% of that resource is in water deeper than 1,000 m. In order to unlock that significant potential, applicants should propose innovative mooring systems and technologies that are technically feasible and economical for floating wind turbines in deep waters (over 1000m depth) [1,2].

- **Innovation in manufacturing, materials and components:** Increasing the capacity factor of a turbine through lower specific power rotors (longer blades) involves tradeoffs between energy capture and turbine structural loads, in addition to transportation constraints. Blade transportation challenges are caused by the difficulty of transporting long, wide blades around turns, through narrow passages, and beneath overhead obstructions on U.S. roads and railways. This challenge generally limits the length of the blade that can be transported over roadways to between 53 and 62m. DOE is seeking applicants to propose innovative technologies that overcome transportation constraints for rotor blades longer than 65m, including, but not limited to on-site manufacturing, segmented blades, and new materials. The technology should be able to enable rotors that have a specific power of 150 W/m^2. [3]

- **Advanced Manufacturing and Recycling:** The end-of-life options for wind turbines are second-hand markets, refurbishing, recycling, and depositing. Turbine blades are made from composites which are designed to optimize performance and reduce weight and loads on the turbine. To date, however, these blades have not been designed with end-of-life recycling. There is a need for more R&D on composite materials for more efficient use and substitution in future designs; to dismantle wind turbines into recyclable materials; and to look at the potential markets for products made from recycled materials. Additionally, better data is needed for the recycling of wind turbine components and materials, especially blades, as uncertainties in data on recycling have a big influence on the LCA of the turbines. Technologies for recycling composite materials are now available, but the investment and operating costs are high, so commercial applications have therefore been very limited. DOE is seeking applications which address the high investment and processing costs to recycle wind turbine blades, for the existing fleet and/or development of new blade materials that can facilitate recycling in the next generation of blades. This application should indicate the cost savings of recycling and how that offsets the decommissioning costs. [3,4]

Questions – Contact: Michael Derby, michael.derby@ee.doe.gov.

c. Other

In addition to the specific subtopics listed above, WETO invites grant applications in other areas relevant to this Topic that enable wind power nationwide.

Questions – Contact: Michael Derby, michael.derby@ee.doe.gov.

References: Subtopic a:

1. Distributed Wind Energy Association (DWEA), 2015, DWEA Distributed Wind Vision – 2015-2030 Strategies to Reach 30 GW of "Behind-the-Meter" Wind Generation by 2030, p. 26. http://distributedwind.org/wp-content/uploads/2012/08/DWEA-Distributed-Wind-Vision.pdf

2. Jenkins, J., Rhoads-Weaver, H., Forsyth, T., et al., 2013, SMART Wind Roadmap: A Consensus-Based, Shared-Vision Sustainable Manufacturing, Advanced Research & Technology Action Plan for Distributed Wind, Distributed Wind Energy Association, Durango, Colorado, p. 110. http://distributedwind.org/wp-content/uploads/2016/05/SMART-Wind-Roadmap.pdf

References: Subtopic b:

1. U.S. Department of Energy, 2015, Wind Vision: A New Era for Wind Power in the United States, p. 289, doi:10.2172/1220428. http://energy.gov/sites/prod/files/2015/03/f20/wv_full_report.pdf

2. U.S. Department of Interior, 2016, National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States, U.S. Department of Energy, p. 84. http://energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategy-report-09082016.pdf

3. U.S. Department of Energy, 2015, Enabling Wind Power Nationwide, p. 43, doi:10.2172/1220457. http://energy.gov/sites/prod/files/2015/05/f22/Enabling-Wind-Power-Nationwide_18MAY2015_FINAL.pdf

4. Larsen, H.H. and Sønderberg Petersen, L., 2014, DTU International Energy Report 2014: Wind Energy — Drivers and Barriers for Higher Shares of Wind in the Global Power Generation Mix, Technical University of Denmark, p. 91-97. http://orbit.dtu.dk/files/102457047/DTU_INTL_ENERGY_REP_2014_WIND.pdf

15. WATER

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

The Office of Energy Efficiency and Renewable Energy's Water Power Technologies Office (WPTO) (http://energy.gov/eere/water/water-power-program) seeks applications for developing environmentally-acceptable lubricants for hydropower applications. WPTO's research portfolio is aimed at producing the next generation of water power technologies and jump-starting private sector innovations critical to the country's long-term economic growth, energy security, and global competitiveness by accelerating the development of markets for those technologies. Achieving full potential for future hydropower growth in the United States requires overcoming a number of key technological, environmental, and market challenges. Specifically, WPTO is working to reduce environmental impacts of hydropower development and operation by investing in tools and methods to develop, demonstrate, and validate environmentally-friendly technologies.

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. MYPP or Roadmap 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 and;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Development of Environmentally-Acceptable Lubricants for Hydropower Applications

A hydropower facility consists of many structures and equipment, both electrical and mechanical (e.g. turbine, generator, governor, transformer, gates and valves, pressurized hydraulic fluid actuators), that invariably require lubricants and hydraulic fluids to operate efficiently. Lubricants—whether oils or greases—help reduce friction, dissipate heat, prevent oxidation, and seal off water and debris. Further, hydropower equipment may often be submerged and components may come in contact with water. Petroleum based lubricants and hydraulic fluids are widely used as these are available at low costs and possess desirable performance characteristics for a wide range of applications. However these lubricants have low biodegradability and can be toxic. Hydropower is typically developed in river systems which also provide water for irrigation and drinking water supply. As such, hydropower lubricants and hydraulic fluids can present a threat to water resources and aquatic ecosystems, especially if unexpected leakages or spills occur. Such spills/discharges in water bodies may also result in local, state and/or federal penalties. Consequently the cost of energy increases due to higher operation and maintenance costs. These penalties may be avoidable if environmentally-acceptable lubricants and hydraulic fluids are used.

WPTO seeks to fund research and development of environmentally-acceptable lubricants (EALs), including hydraulic fluids, that can achieve high performance with minimal adverse effects on the water systems and aquatic environment in the event of its contact with water or a spill. The Environmental Protection Agency (EPA) defines EALs as "those lubricants that have been demonstrated to meet standards for biodegradability, toxicity and bioaccumulation potential that minimize their likely adverse consequences in the aquatic environment, compared to conventional lubricants.” [1]

Awards under this topic will carry out early-stage, proof-of-concept research into EAL formulations for hydropower applications, including laboratory testing for a limited number of EALs in Phase I. In Phase II the awardee(s) will continue to complete the development of a suite of EALs for hydropower applications. During Phase II, DOE may consider providing additional resources for up to 150 labor-hours at one or more national laboratories time in addition to the SBIR/STTR funding to the applicants if needed. Such national laboratory resources may be useful to assess and test the ecological performance of the developed formulations. Examples of resources provided include support for a peer review of the work done in Phase I; determination of toxicity with respect to various types of fish and other aquatic species in the presence of the newly developed EALs; and evaluation of the performance characteristics for the intended application. If the applicant(s) desire such national laboratory resources they must include a description resources required.

Applicants must also demonstrate knowledge, experience, and capabilities in developing lubricants and include the following in their application:

- A description of various uses of lubricants and hydraulic fluids for hydropower equipment along with the types of lubricants and hydraulic fluids that are currently in use including any EALs;
- The state-of-the-art EALs currently in use by other industries and the need for new and/or additional formulations;
- Federal and State requirements for the targeted EALs market;
- Strategy for developing a suite of future EALs for use by the hydropower industry;
- Target equipment and component(s);
- Fluid performance characteristics for each formulation under consideration including environmental performance, toxicity and biodegradability;
- Details of work to be performed in Phase I including the test plan for performance of the EALs – both for the intended use and environmental acceptability;
- Description of Phase II work including use of national lab resources if desired by the applicant;

Applicants should also detail how they propose to utilize the grant to advance the state-of-the-art, and, if successful, the commercialization plan for the EALs to be developed under this topic.

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

References: Subtopic a:

1. Office of Wastewater Management, 2011, Environmentally Acceptable Lubricants, U.S. Environmental Protection Agency, p. 24. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100DCJI.txt

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.

16. 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 STTR Phase I 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. These new methods and processes would be of benefit to DOE-EM and other commercial applications involving subsurface monitoring. 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 four broad themes:

- Provide dust suppression alternatives to the use of water for large open areas
- Develop vadose zone pore water sampler
- Develop two-dimensional surveys (walkover, drone, and overflight) for long-term monitoring of residual contamination. These techniques might include geophysical or other remote sensing

techniques that allow for spatial delineation of contaminant changes through time (e.g. Chromate at Hanford, Rads including I and Tc at SRS)
- Innovative methods for delivery of treatment amendments to increase spatial distribution in complex geology (fractures rock at substantial depths of 1000 feet

a. Provide Dust Suppression Alternatives to the Use of Water for Large Open Areas

The office of Environmental Management has several sites that require dust suppression while moving contaminated materials to landfills. The dust suppression with water cause the subsurface contaminants to be transported toward receptors which affect the health of sensitive ecosystems. EM is in need of dust suppression methods other than water to prevent this migration of contamination in the subsurface.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Skip Chamberlain, grover.chamberlain@em.doe.gov

b. Develop Vadose Zone Pore Water Sampler

EM has multiple sites with deep vadose contamination. These sites need to be able to sample pore water in the subsurface to determine the fate and transport of any contamination.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Skip Chamberlain, grover.chamberlain@em.doe.gov

c. Develop Two-Dimensional Surveys (Walkover, Drone, and Overflight) for Long-Term Monitoring of Residual Contamination. These techniques might include geophysical or other remote sensing techniques that allow for spatial delineation of contaminant changes through time (e.g. Chromate at Hanford, Rads including I and Tc at SRS)

EM has several sites and sites with are buildings that require remote sensing due to the contamination in the area. EM needs to be able to track any changes over time to the spatial distribution of contamination. (Hanford (http://www.hanford.gov/); Paducah (https://energy.gov/pppo/paducah-site); Los Alamos (https://energy.gov/em-la/environmental-management-los-alamos-field-office).

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Skip Chamberlain, grover.chamberlain@em.doe.gov

d. Innovative Methods for Delivery of Treatment Amendments to Increase Spatial Distribution in Complex Geology (Fractures Rock at Substantial Depths of 1000 Feet)

EM has a need for innovative methods of the delivery of amendments to treat contaminants in deep areas. Contaminants are dispersed and require delivery in a wide area in difficult geology such as fractured rock at substantial depth. (Los Alamos: https://energy.gov/em-la/environmental-management-los-alamos-field-office)

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Skip Chamberlain, grover.chamberlain@em.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: Latrincy Bates, Latrincy.Bates@em.doe.gov or Skip Chamberlain, grover.chamberlain@em.doe.gov

PROGRAM OFFICE OVERVIEW – OFFICE OF FOSSIL ENERGY

The U.S. Department of Energy's Office of Fossil Energy (FE) plays a key role in helping the United States meet its continually growing need for secure, reasonably priced and environmentally sound fossil energy supplies. FE's primary mission is to ensure the nation can continue to rely on traditional resources for clean, secure and affordable energy while enhancing environmental protection.

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 promote the secure, efficient and environmentally sound production and use of America's abundant fossil fuels in both existing and new infrastructure. To this end FE is, once again, concentrating its 2018 Phase I SBIR-STTR effort on two areas that significantly support and enable development of several fossil energy technologies: Sensors & Controls and Advanced Manufacturing & Materials.

For additional information regarding the Office of Fossil Energy priorities, visit https://www.energy.gov/fe/mission

17. SENSORS AND CONTROLS FOR FOSSIL ENERGY APPLICATIONS

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

Advanced sensors and controls enhance the reliability, efficiency, economics, and operational flexibility of fossil energy applications. Research includes sensors capable of monitoring key operational parameters (temperature, pressure, and gas compositions) while operating in harsh environments; analytical sensors capable of on-line, real-time evaluation and measurement; diagnostics tools for the oil and gas industry; and field detection sensors for rare earth elements processing equipment. Controls development centers around self-organizing information networks, algorithms for component lifetime assessment and plant-level economics, and distributed intelligence for process control and decision making. Additionally, this topic leverages technology trends in data transfer (e.g. Blockchain) and data analytics as well as developing technologies to enhance resiliency and harden fossil energy assets.

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.

Grant applications are sought in the following subtopics:

a. Automated Situational Awareness Technologies for Robust and Resilient Fossil Energy Power Generation
U.S. Power Generation assets are increasingly vulnerable to attack by malicious attack both from insider threats and cybercriminals. The potential consequences of these vulnerabilities, if not mitigated, were illustrated in December of 2015 by a coordinated cyber-attack on Ukrainian power infrastructure. Key to the success of those attacks was a lack of situational awareness by system operators. Had the operators known of the initial intrusion, they could have acted to mitigate the ultimate outcome. In the United States, the power generation utility sector has been taking steps to improve its readiness consistent with the North American Electric Reliability Corporation (NERC) reliability requirements. Digital automation trends involving the addition of numerous distributed sensing nodes to the power plant, the communication of data – often wirelessly, and the multitude of data available to the operators creates a

situation where automated data analytics and controls are essential both to optimize plant operability as well as mitigate malicious behavior. While there have been advancements in automated situational awareness tools for power distribution, none exist thus far that can be readily implemented to protect fossil power generation assets.

This subtopic requests proposals to develop automated situational awareness tools to enhance the reliability of the fossil power fleet. Tools are needed that can constantly scan a multitude of sensor data to assess the health of the power plant as well as to recognize malicious behavior and automatically trigger counter measures to mitigate it. Fossil power generation infrastructure ranges from relatively new gas turbine combined cycles to 50-year-old coal power plants in various states of control system infrastructure modernization. The utility sector also ranges from individual municipalities to investor owned utilities and each may take a different approach to realize its preferred risk posture while remaining NERC compliant.

Questions – Contact: Sydni Credle, sydni.credle@netl.doe.gov

b. Sensor Development to Enable Feed-Forward Control of Distributed Modular Energy Systems

Emerging Fossil Energy (FE)-based modular power systems are anticipated to achieve higher efficiencies, lower emissions, improved reliability and availability (lower total operating costs), and stable control and operation through development of feed-forward control systems. The feed-forward control system would have sufficient performance mapping to handle variations in feed and environmental conditions. However, there exists a need for the commercial sector to develop real-time sensors to measure feedstock properties and process conditions at inlet and outlet.

Applications are sought to develop real-time sensing technology to enable feed-forward control technology for modular power generation systems. Sensing capabilities of interest include, but are not limited to, measuring inlet conditions of solid fuel feed (e.g. coal, biomass, solid wastes) such as particle size, moisture content, ash content, and fuel heating value. Process measurements of interest include unconverted carbon in residual, syngas chemical composition (both major and minor species), detection of solids flow in transport reactor and fluid bed applications. Downstream measurements are also desired which include flow, pressure, temperature, and chemical makeup.

This topic area is open to any innovative techniques to employ advanced sensors, including but not limited to embedding of sensors in refractory, fiber optic sensors, solid state sensors, and other techniques to accomplish stated need. Ideally, sensors could find application in coal conversion systems that would be called upon to operate in flex-fuel mode via fuel blending with low-cost feedstocks such as biomass, municipal solid waste. Advances in this topic are anticipated to result in commercial viability of flexible fuel distributed energy systems to remote areas and operation without need for highly-specialized training, thus allowing for employment of locally-available labor force.

Questions – Contact: Steven Markovich, steven.markovich@netl.doe.gov

c. Other

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

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

References: Subtopic a:

1. Symantec Security Response, 2017, Dragonfly: Western Energy Sector Targeted by Sophisticated Attack Group: Resurgence in Energy Sector Attacks, with the Potential for Sabotage, Linked to Re-emergence of Dragonfly Cyber Espionage Group, Symantec Connect. https://www.symantec.com/connect/blogs/dragonfly-western-energy-sector-targeted-sophisticated-attack-group

2. Lee, R. M., Assante, M. J., and Conway, T., 2016, Analysis of the Cyber Attack on the Ukrainian Power Grid, North American Electric Reliability Corporation. http://www.nerc.com/pa/CI/ESISAC/Documents/E-ISAC_SANS_Ukraine_DUC_18Mar2016.pdf

3. National Energy Technology Laboratory (NETL), 2017, Crosscutting Research Program: Sensors and Controls Project Portfolio, U.S. Department of Energy. https://www.netl.doe.gov/File%20Library/Research/Coal/cross-cutting%20research/2017-CCR-Sensors-and-Controls.pdf

4. Butun, I., Morgera, S. D., and Sankar, R., 2014, A Survey of Intrusion Detection Systems in Wireless Sensor Networks, IEEE Communications Surveys & Tutorials, Volume 16, Issue 1, p. 266-282. http://ieeexplore.ieee.org/document/6517052/

5. National Institute of Standards and Technology, 2017, Situational Awareness: a New Way to Attack Cybersecurity Issues Rather Than Using a System Defense Approach, NIST, p. 4. https://www.nist.gov/sites/default/files/documents/2017/04/26/tri-county_electric_cooperative_part2_032613.pdf

References: Subtopic b:

1. National Energy Technology Laboratory, 2017, Specifically the (1) Modular Gasification Systems Workshop Panel Presentations and (2) GASIFICATION SYSTEMS Presentations https://www.netl.doe.gov/events/conference-proceedings/2017/2017-project-review-meeting-for-crosscutting-research-gasification-systems-and-rare-earth-elements-research-portfolios

2. Kopyscinski, J., Schildhauer, T. J., and Biollaz, S. M. A., 2010, Production of synthetic natural gas (SNG) from coal and dry biomass – A technology review from 1950 to 2009, Fuel, Volume 89, Issue 8, p. 1763-1783. http://www.sciencedirect.com/science/article/pii/S0016236110000359

3. Sahraei, M. H., McCalden, D., Hughes, R., et al, 2014, A survey on current advanced IGCC power plant technologies, sensors and control systems, Fuel, Volume 137, p. 245-259. http://www.sciencedirect.com/science/article/pii/S0016236114007376

18. ADVANCED MANUFACTURING & MATERIALS FOR FOSSIL ENERGY TECHNOLOGIES

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

Advanced manufacturing has the potential to transform the nation's fossil energy resource potential into affordable energy to foster economic growth, jobs, and national security. Advanced manufacturing can be used to improve existing manufacturing processes and rapidly introduce new prototypes and products spanning the entire fossil value chain and fossil energy sources including coal and coal-by products, oil, natural gas, and natural gas liquids. These paradigm-shifting aspects of advanced manufacturing offers the potential to spin off entirely new industries and lead to production methods that are most likely to remain in the United States because they are hard to imitate. Advanced manufacturing may also be defined in terms of improvements in: lifecycle energy use, cost reduction, time-to-market, reliability, and environmental footprint. Synergistic technology trends including data analytics, robotics, design tools, and nano-engineering of materials. Hence, profitable application improvements leveraging advanced manufacturing often take the form of integrated technology solutions. Finally, advanced manufacturing is enabling the realization of components and technologies that benefit from advanced, difficult-to-process and/or expensive, materials with exceptional service properties such as nickel super-alloys and high-temperature ceramics.

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.

Grant applications are sought in the following subtopics:

a. Thermal-Environmental Barrier Coating (T-EBC) System for Ceramic Matrix Composites (CMCs) Turbine Components

Among the goals of the Advanced Turbines Program is to develop and evaluate advanced materials and concepts to improve capabilities for withstanding much higher temperatures for turbines hot gas path components (e.g. with turbine inlet temperatures exceeding 3,100°F) needed to achieve combined cycle energy efficiencies greater than 65%. Ceramic matrix composites (CMCs) have been a material of interest for gas turbine components with operating temperatures 200°-300°F higher than typical super-alloy materials. In order to use these CMCs in such an extreme temperature and reactive gas environment, the development of a thermal-environmental barrier coating (T-EBC) that is stable at high temperatures is required. The T-EBC must provide protection against corrosive gases and reduce the temperature of the CMC to acceptable levels, and withstand thermal shock while retaining their refractory properties and mechanical strength during operation. While T-EBC protective coatings have been developed for current CMC engine applications, none exists for 3100 F applications.

Grant applications are sought for the design, development and evaluation of a thermal-environmental barrier coating (T-EBC) system that will protect and permit the reliable operation of silicon carbide (or other silicon based) composites at combustion gas temperatures approaching 3100 F. Applications must show that the developed T-EBCs are thermochemically stable, highly impervious to moisture and oxygen transport, phase-stable over the temperature range of interest, tolerant to thermal strains, and resistant to impact from foreign particles. In addition to these requirements, the T-EBCs must be erosion resistant and must include a stable bond coat capable of exposure to high temperatures for long periods. Fulfillment of each of these requirements is the main objective of the grant. Research focused on advancing the use and applicability of materials made by additive manufacturing and/or other advanced manufacturing practices will also be of great interest.

This subtopic area directly relates to innovative technologies that show promise in harnessing American energy resources safely and efficiently and reflects the later-stage research, development, and commercialization of energy technologies, and is therefore well-aligned with the R&D Priority Areas (as described in the recent OMB memo on FY 2019 Administration Research and Development Budget Priorities) targeting American Energy Dominance.

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

b. Additive Manufacturing of Extreme Environment Materials for Large Parts

DOE is currently exploring a suite of transformational technologies for fossil energy-based power production, including (but not limited to) supercritical CO2 (sCO2) cycles, chemical looping combustion (CLC), direct power extraction (DPE), and pressurized combustion. Development of extreme environment materials (EEM) and related advanced manufacturing processes for system components that are able to withstand the typically harsh environments observed for these FE components while also achieving sought-after performance is critical. Additive manufacturing (AM) is of great interest for the production of fossil energy-based system components due to its ability to allow flexibility of design, production of complex parts, and lower cost due to reduced materials requirement, decreased lead times, etc. (Frazier, 2014). However, the ability of AM to produce dimensionally large parts from EEM is lacking (ORNL, 2016) and more R&D is needed to realize the full potential of AM as a viable alternative to traditional manufacturing processes (i.e. investment casting, hot isostatic pressing, etc.) (Mercelis, 2006; Gu, 2012; Gong, 2012; Williams, 2016).

Proposals are sought to explore scale-up of additive manufacturing (AM) processes for extreme environment materials (EEM) such as nickel-based superalloys, ceramics, and refractory alloys. Target application would be any fossil energy-relevant system component with a major axis of greater than 4 feet.

Applicants must specify the fossil energy component of interest, relevant specification for material performance (microstructure, mechanical properties, etc.), proposed additive manufacturing approach, and summary of critical fabrication issues including relevant mitigation techniques. Manufacturing process modeling for microstructural design and performance prediction of AM-fabricated parts is encouraged. Project objectives will include material procurement and preliminary experimentation to prove feasibility of the stated manufacturing approach. Methodology for possible full-scale production of target component as well as approach for relevant testing to confirm microstructural and mechanical integrity must also be provided.

Questions – Contact: Richard Dunst, richard.dunst@netl.doe.gov

c. High Value Products from Coal

Domestic coal can be used to manufacture solid carbon products including carbon fiber, battery/electrode materials, carbon-based photovoltaics, carbon materials for 3D printing applications, carbon-based construction materials, and carbon additives for manufacturing composites. The market value of these high-performance materials often exceeds the fuel and heat value of coal, which illustrates there are sustainable market forces for manufacturing carbon materials from coal.

Proposals are sought that focus on using domestic coal and closely related by-products (pitch, char) as a manufacturing feedstock to produce carbon materials and composites. Utilizing coal for producing carbon materials creates new business opportunities by integrating coal into the value-chain of industries that typically do not use coal in their manufacturing processes. Coal-based carbon fiber and carbon fiber reinforced polymers offer opportunities for producing new forms of lightweight structural materials and composites which have utility in automotive and aerospace applications. Coal-based carbon nanomaterials, such as graphene and carbon quantum dots, offer opportunities to bring down the costs of these materials so they can be used in electronic display screens, pigments/dyes/coatings, enhanced textiles, and structural composites. Inexpensive carbon nanomaterials can also be used in 3D printing fluids/plastics to enhance the electrical/thermal/optical properties of the final printed material. Coal-based coke, pitch, and carbon nanomaterials can be used to produce electrode materials for a range of applications such as aluminum production, batteries/energy storage, and supercapacitors.

Questions – Contact: Barbara Carney, barbara.carney@netl.doe.gov

d. Novel Materials or Processes to Support Transformational Carbon Capture Technologies

Among the objectives of the Carbon Capture Program is to support the development of transformational technologies for a new coal-fired power plant with CO2 capture with 95% purity and with a cost of electricity at least 30% lower than a supercritical PC with CO2 capture, or approximately $30 per tonne of CO2 captured. The technologies can include both materials and processes used for advanced carbon capture.

Grant applications are sought for novel materials including membranes, sorbents, solvents or hybrid materials that have NEVER been examined for the purpose of carbon capture. The results of a literature review will be necessary to demonstrate the novel nature of the proposed material. Additionally, grant applications are also sought for novel process concepts that will lead to an improvement in the overall cost of carbon capture systems. Applications must show that the materials or processes have the potential to provide a significant improvement in cost and/or performance of carbon capture systems.

This subtopic area directly relates to harnessing American energy resources safely, efficiently and in an environmentally sound manner. It reflects an investment in early-stage, innovative technologies and is therefore well-aligned with the R&D Priority Areas (as described in the recent OMB memo on FY 2019 Administration Research and Development Budget Priorities) targeting American Energy Dominance.

Questions – Contact: I. Andrew Aurelio, isaac.aurelio@netl.doe.gov

e. Other

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

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

References: Subtopic a:

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19. OIL AND GAS TECHNOLOGIES

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

The dramatic increase in domestic natural gas production from shale source rocks is increasing our reliance on natural gas as a critical contributor to the national energy supply. Ensuring the integrity and reliability of our natural gas transportation and delivery infrastructure has always been important, but will become even more so as our reliance on natural gas grows over coming decades.

Natural gas pipelines —gathering lines, intrastate lines, interstate transmission lines and distribution systems —are a part of this infrastructure that will require increased surveillance and more effective inspection capabilities over coming decades as large segments of these systems reach maturity. This is particularly important as aging systems are called upon to deliver increasing amounts of gas to end users.

Dramatic increases in the number of producing gas wells, often horizontal wells tapping deeper reservoirs in populated areas, will also require increased vigilance on the part of industry and regulators to ensure that wellbore integrity is maintained during what will likely be the long producing lives of such wells. Increased use of natural gas storage facilities, which in many cases utilize abandoned gas reservoirs with older wellbores, will require cost-effective methods for ensuring wellbore integrity so that deliverability and safety are not compromised (e.g., the 2015 Aliso Canyon leak).

DOE is interested in catalyzing the development of novel technologies that will improve our ability to inspect, monitor and repair natural gas pipelines. DOE is currently funding several projects directly or indirectly related to this topic (e.g., NETL, 2017) but believes that there is still a need for more research in this area.

In addition, DOE is interested in funding research to develop technologies that can help industry more quickly and cost effectively assess the integrity of both casing and cement barriers to subsurface flow in new or old wellbores.

Beyond-state-of-the-art research that can have (or lead to) "game-changing" impacts on these two elements of the Nation's natural gas transport and delivery infrastructure will be considered more responsive to this solicitation than research that proposes small, incremental advances.

Grant applications are sought in the following subtopics:

a. Midstream/Onshore Pipeline Infrastructure Integrity and Safety

In the United States, there are over 400 thousand miles of transmission pipeline and over one million miles of aging distribution pipeline in use. Considering this vast network of pipeline systems, there is a need to develop economical approaches to monitor and inspect these systems against sabotage and failure.

DOE has projects that have focused on the development of low-cost monitoring and inspection tool (CTC), internal pipeline coating systems for inhibiting/monitoring corrosion and effective methane mitigation (Oceanit & PPG). The DOE is interested in building upon its existing research portfolio by developing new ways to economically monitor pipeline integrity, detect and diagnose incipient defects, leaks, and failures, inhibit methane leakage and protect new and existing U.S. pipeline systems against potential resource theft and/or sabotage.

Specific concepts could include: advanced pipeline inspection and repair tools, advanced "smart" sensor systems for monitoring pipeline integrity, advanced self-healing coatings development and deployment technique for methane mitigation, and internal pipeline sensors/coating systems that can communicate a variety of operational parameters.

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

b. Improving Wellbore Integrity and Diagnostics

Ensuring wellbore integrity is of critical importance, particularly as increasing numbers of wells are being drilled and hydraulically fractured in areas with large populations that rely on subsurface sources of drinking water. In addition, there is a growing need to be able to quickly and cost-effectively assess the condition of older producing or gas storage wells where casing integrity may be an issue.

While many companies have instituted best practices that reduce the risk of aquifer contamination due to inadequate cement jobs, novel technologies that can be utilized to assess wells of all vintages could reduce this risk even further.

Under this Subtopic, DOE is interested in research that leads to the development of more cost-effective tools or methods for:

- Investigating rock/cement/casing bond integrity and how it is affected by corrosion, thermal cycling, and/or long term injection or production of fluids
- Measuring hydraulic containment, casing stress state, cement condition, corrosion activity, and fluid chemistry over time in cased wellbores

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

c. Other

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

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF FUSION ENERGY SCIENCES

The mission of the Fusion Energy Sciences (FES) program 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 through the study of plasma, the fourth state of matter, and how it interacts with its surroundings. 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.

The next frontier for fusion research is the study of the burning plasma state, in which the fusion process itself provides the dominant heat source for sustaining the plasma temperature (i.e., self-heating). Production of strongly self-heated fusion plasmas will allow the discovery and study of new scientific phenomena relevant to fusion energy, including the properties of materials in the presence of high heat and particle fluxes and neutron irradiation.

To achieve its research goals, FES invests in flexible U.S. experimental facilities of various scales, international partnerships leveraging U.S. expertise, large-scale numerical simulations based on experimentally validated theoretical models, development of advanced fusion-relevant materials, and invention of new measurement techniques.

FES also supports discovery plasma science, including research in laboratory plasma astrophysics, low-temperature plasmas, small-scale magnetized plasma experimental platforms, and high-energy-density laboratory plasmas.

Research supported by FES has led to many spinoff applications and enabling technologies with considerable economic and societal impact.

The following topics are restricted to advanced technologies and materials for fusion energy systems, fusion science, technology relevant to magnetically confined plasmas, and low-temperature plasmas, as described below.

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

IMPORTANT CHANGE FOR FY 2018: FES is reducing the number of SBIR/STTR topics and subtopics beginning in FY 2018. This action is being taken because FES has historically received a much greater number of high quality proposals that it cannot fund each year. The impact for FY 2018 is that the following topics and subtopics will not be included in FY 2018, but are planned to be included in FY 2019. (Some FY 2018 topics may not appear in FY 2019):

- ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS
- Plasma Facing Components

- Blanket and Safety Technologies
- Structural Materials and Coatings
- HIGH ENERGY DENSITY PLASMAS
- Laser Technologies
- Ultrafast Diagnostics

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 STTR Phase I Applications: YES

An attractive fusion energy source will require the development of superconducting magnets. This technology 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. 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 14 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

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: Barry Sullivan, barry.sullivan@science.doe.gov

References: Subtopic a:

1. United States Department of Energy, Office of Fusion Energy Sciences, 2009, Research Needs for Magnetic Fusion Energy Sciences, Report of the Research Needs Workshop (ReNeW), p. 285-292. http://science.energy.gov/~/media/fes/pdf/workshop-reports/Res_needs_mag_fusion_report_june_2009.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 STTR Phase I Applications: YES

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) simulation, control, and data analysis for magnetically confined plasmas, and (d) small scale experiments on stellarators, spherical tori, and reversed field pinches. 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 understand, predict, and control fusion plasmas. Applications are sought for the development of advanced diagnostic techniques and technology to (i) enable new ways of studying plasma behavior in both existing and new plasma regimes, (ii) measure plasma parameters not previously accessible, (iii) increase the capabilities of existing diagnostics, and/or (iv) reduce substantially the complexity of existing diagnostics. Development of diagnostics meeting the needs for advancing the science of burning plasmas, boundary and pedestal physics, transient events (including ELMs and disruptions), plasma-material interactions, and long-pulse magnetized plasmas are particularly welcome. Proposals that have also a broader applicability are encouraged.

All applications should specifically identify the strong potential for commercialization of the proposed innovations on a schedule that is consistent with the award timeline and sequence of the DOE SBIR and STTR Programs. Ideally, the proposed customer base should extend into the private sector. Accordingly, work that is normally funded by program funds, or that culminates only in the awarding of future program funds, should not be proposed. Furthermore, requests seeking funding for the routine application or operation of mature diagnostic techniques will not be considered.

Questions – Contact: Matthew Lanctot , matthew.lanctot@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 advanced components are needed 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) technologies for managing and analyzing large volumes of complex scientific data; and (4) collaboration tools that enhance the ability of scientists to lead and participate in experimental operations on remote facilities.

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 that 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

References: Subtopic b:

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References: Subtopic d:

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22. PLASMA APPLICATIONS

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

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.

One of the prime opportunity for new applications is in the area of low temperature plasmas. 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. All Low temperature plasma 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. Low-Temperature Plasma Chemistry for a Cleaner Environment

Clean supplies of energy, water and air constitute some of the largest global issues for the near future. Low temperature plasmas offer a possible path to these supplies. Examples include the generation of syngas, as a catalyst for changing CO_2 into carbonates, efficient small scale generation of NH_3, and the generation of liquid transportation fuels from CO_2. Low temperature plasmas chemistry also show promise in the area of purification of recycled and polluted water by disinfecting it and degrading organic pollutants. Chemical processing leaves residual toxicity, while ultraviolet processing inefficiently consumes electricity, and neither method degrades all pharmaceuticals. Techniques using plasmas for supplies of clean energy, water and air are sought.

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

d. Other

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

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

References:

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PROGRAM AREA OVERVIEW: OFFICE OF HIGH ENERGY PHYSICS

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 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, often 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 Fermilab complex includes the Main Injector (which formerly fed the now dormant Tevatron ring), which is used to create high-energy particle beams for physics experiments, including the world's most intense neutrino beam. The Main Injector is undergoing upgrades to support the operation of Fermilab's present and planned suite of neutrino and muon experiments at the Intensity Frontier. A new Fermilab facility in development, called PIP-II (Proton Improvement Plan II) will greatly increase the intensity of proton beams sent to the Main Injector. 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 used for the Facility for Advanced Accelerator Experimental Tests (FACET), now undergoing an upgrade called FACET-II. At Argonne National Laboratory, also near Chicago, resides the Argonne Wakefield Accelerator (AWA) facility, which houses two test electron accelerators, one for 15 MeV electrons, and the other for 70 MeV electrons. Experiments focus on two-beam and collinear wakefield acceleration as well as tests of novel accelerator structures and beam-line components. Brookhaven National Laboratory operates the Accelerator Test Facility, which supports accelerator science and technology demonstrations with electron and laser beams. 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.

23. 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 STTR Phase I Applications: YES

The DOE 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.

Grant applications are sought only in the following subtopics:

a. 3D Printing of Accelerator Components

Grant application are sought to develop exotic metal powders for use in Binder Jetting, Direct Metal Laser Sintering, or Bound Metal Deposition 3D printers for accelerator components. Exotic metal materials for Binder Jetting, Direct Metal Laser Sintering, and Bound Metal Deposition 3D printing of accelerator components. Many accelerator components must be produced from exotic metals for various beam physics and engineering reasons. An example is the use of niobium for superconducting RF cavities and ancillary components. Current production methods utilize machining and welding, and make fabrication of complex geometries difficult, slow, and costly. 3D printing allows complex geometries to be fabricated easily and quickly, but a lot of the exotic materials are not available for printing yet. Binder Jetting and Bound Metal Deposition printers offer a relatively low cost of entry into metal 3D printing, and use standard Metal Injection Molding (MIM) powders as feed material. Direct Metal Laser Sintering (DMLS) printers cost more, and utilize special uniform grain size powders as their feed material. Development of exotic metal powders (such as niobium) for any of these 3 printing processes would open 3D printing as an option for the production of complex accelerator components.

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

b. Wakefield Acceleration

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. In particular, transverse tailoring to produce nearly 'hollow' profiles with very low on axis density while maintaining laser guiding is important to create the desired magnitude of focusing forces for the electron beam and to mitigate scattering induced degradation of electron beam emittance while also providing laser guiding. Longitudinal tailoring along the direction of laser propagation enables particle injection control via modulation of the plasma wave phase velocity to induce injection. Approaches could include the use of pulsed gas jets, clustered gas jets or capillary structures. Hydrogen plasmas or clusters are important to enable use of the resulting plasma for high intensity laser targets, and high repetition rate (≥10 Hz) is needed. For clustered targets, carefully controlled size/composition, and high mean density, is important to density tailoring.

Grant applications are sought for efficient 3D modeling of capillary discharge plasmas. Fundamental improvements to the energy, brightness, stability, and repeatability of lepton beams from plasma-based accelerators in the next generation of experiments will require fundamental improvements in the understanding, design, and control of the plasmas used for both injection and acceleration, including tailored 3D density profiles [1,2]. For example, an efficient laser plasma accelerator (LPA) [1] requires the laser pulse to propagate many Rayleigh lengths without diffraction; this is accomplished via plasma columns that minimize plasma density along the laser propagation axis [3,4]. For a positron-driven plasma wakefield accelerator (PWFA), optimal wakefields are achieved with hollow or near-hollow plasma channels [5]. Control of the longitudinal plasma density profile is required for down-ramp injection in LPAs and for improved resonant injection in PWFAs. Moreover, the use of capillary discharges as an active plasma lens for relativistic electron beams is under way in a number of experimental facilities around the world [6]. Massively parallel 3D MHD simulations of plasma formation and evolution are required to support plasma accelerator experiments and to fundamentally improve the quality and reliability of the accelerated electron and positron beams.

Grant applications are sought for research on novel electron beam-driven, structure-based wakefield accelerators, either dielectric or metallic, for use in either collinear wakefield accelerators (CWA) or two-beam accelerators (TBA). Electron accelerators achieving accelerating gradients greater than 300 MV/m in the GHz-THz range are sought. [7]

Grant applications are sought for an externally injected main beam source for wakefield accelerators in the GHz-THz regime. Such electron sources must (1) generate linear collider quality beams with ultralow emittance beams (~0.1 micron at ~1nC) and/or (2) utilize longitudinal main beam shaping to achieve high "RF to main beam" efficiency (>=50%). [8]

Grant applications are sought for an electron drive beam source for wakefield acceleration. Alternative techniques for the generation of (i) single drive beams with longitudinally shaped current profile to achieve high transformer ratio (TR>2) and/or (ii) multi-bunch drive trains for advanced accelerators (structure or plasma wakefield) for acceleration of high-brightness beams. [9]

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

c. Beam Diagnostics Tools

Grant applications are sought to develop novel diagnostic techniques for transverse and longitudinal characterization and optimization of high intensity electron and proton beams. The specific research topics of interest include but are not limited to non-intercepting beam profile monitors, halo and beam loss monitors, and time of arrival diagnostics. Techniques that do not intercept the beam are preferred but others will be considered.

In addition, grant applications are sought to develop spatial and temporal diagnostic systems for single electron experiments, such as characterization of a single electron oscillations in a storage ring. [10,11,12] Grant applications are sought to develop low-cost, non-interceptive diagnostics (e.g. charge, position, bunch length) with large dynamic range such as the Argonne Wakefield Accelerator (AWA) drive electron beam (1pC to 100nC) electron bunch. [13]

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

d. Non-Linear Magnets for High Dynamic Aperture Lattices

Grant applications are sought for non-linear magnets for high dynamic aperture lattices. Beam intensity limitations in modern particle accelerators are often dominated by the acceptance and/or dynamic aperture of linear beam optics lattices. Recently, a solution for bounded non-linear motion has been suggested that utilizes specially designed magnetic inserts, resulting in a so-called Integrable Optics (IO) beamline, which can support much larger beam currents than an equivalent linear lattice. It was shown that an IO magnetic lattice could be used to design an integrable Rapid Cycling Synchrotron (iRCS) as a much higher current replacement for the Booster Synchrotron at Fermilab.

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

e. Activation Studies and Shielding Design

Beam halo and the associated particle loss is a limiting factor in accelerator design and operation for both the energy frontier and the intensity frontier, as well as for linac-driven user facilities. Present (and planned) facilities for advanced accelerator concepts continue to increase the peak energy and intensity, as well as the average power of the accelerated electron beams. Beam loss, beam dumps and the associated activation can no longer be ignored if advanced concepts are to be seriously included in the DOE HEP timeline.

Grant applications are sought for each of the following three subtopics:

- To improve, harden, and commercialize community codes capable of simulating 3D hadronic and electromagnetic cascades, muon, heavy-ion and low-energy neutron transport in accelerator, detector and shielding components in the energy range from zero to 100 TeV.
- 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.
- For the conversion of existing codes to incorporate these interfaces (providing 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

f. Electron Lenses

Beam halo and the associated particle loss is a limiting factor in the LHC collider rings. For the high-luminosity upgrade HL-LHC, the collimation system will have to face the challenge of unprecedented beam powers. No suitable beam halo scrapers currently exist.

Collimation with hollow electron beams is a promising advanced concept for active halo control. It was demonstrated at the Fermilab Tevatron collider and it has recently been reviewed and recommended for HL-LHC. Experimental and computational studies of hollow electron lenses and their effect on hadron ring beam dynamics are required to optimize the design and to reduce risk. Electron lenses also show promise for space charge compensation and nonlinear integral optics, both of which could reduce the formation of beam halo at the intensity frontier for hadron rings. Grant applications are sought for development of more accurate simulation and design tools for electron lens systems. [14]

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

g. Other

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

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

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24. 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 STTR Phase I Applications: YES

Radio frequency (RF) technology is a key technology common to all high energy accelerators. RF sources with improved efficiency and accelerating structures with increased accelerating gradient are important for keeping the cost down for future machines. DOE-HEP seeks advances directly relevant to HEP applications, and also 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.

a. Cooling Systems for High-Heat-Density RF Devices

Grant applications are sought for the design and fabrication of a cooling system for high-heat-density RF devices. Specific area of interest includes: Cooling transistors in the high frequency, broadband pulsed power generator for the proposed PIP-II MEBT beam deflector. A minimum requirement is cooling a chain of at least four transistors (200 W/cm2 per transistor) surface mounted on one substrate made from dielectric material having very high thermal conductivity, where the heat should be transferred through the dielectric material to the cooling medium. The heat transfer should not use any electrically conductive material. The mechanical design of the cooling elements should present minimum parasitic capacitance to ground (less than 1 pF per transistor is desirable). Minimum power dissipation per substrate should be at least 120 W. [1,2]

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

b. High Gradient Accelerator Research and Development

Grant applications are sought to develop an advanced ACE3P code for accelerator cavities--normal or superconducting--that allows an automated start-to-end use of CAD within the shape optimization process. Although ACE3P currently incorporates shape optimization algorithms, it does not support the start-to-end use of CAD within the overall optimization process. Users of ACE3P must therefore stop the workflow and manually update the cavity design variables before proceeding. Shape optimization techniques that iteratively link the optimization algorithms in ACE3P to a CAD model of the cavity would facilitate mesh adaptation and generation at each step of the optimization cycle and alleviate the time-consuming need for manual intervention. This topic therefore requests a new cavity shape optimization code that integrates the workflow between one start-to-end ACE3P cycle, a CAD tool to update the cavity design based on ACE3P, the meshing tool, and the next ACE3P cycle. [3]

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

c. High Efficiency High Average Power RF Sources

Future high power accelerators will require highly efficient sources of megawatt-class radiofrequency power. R&D to significantly improve the power efficiency of high-average-power (CW or high duty factor) radiofrequency tubes is sought. 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

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

References:

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25. 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 STTR Phase I 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 (1) ultrafast lasers capable of high average power (kilowatt-class) operating at the high electrical-to-optical efficiency (>20%) needed for advanced accelerator applications, and (2) high average power custom-pulse-structure lasers for beam manipulation and diagnosis.

In category (1), accelerator applications of ultrafast lasers call for one of the following 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%

In category (2), longer-pulse lasers are finding increasing application in the control and diagnosis of proton and H-minus beams. Near IR lasers are used in a variety of applications ranging from partial neutralization of H-minus beams (0.75 eV binding energy) for diagnostics to total neutralization (for notching and phase space sculpting). UV lasers are used for stripping neutral hydrogen beams (13.6 eV binding energy) by resonantly exciting the atom, then Lorentz stripping the more loosely bound electron in a strong magnetic field. As proton machines move steadily into the megawatt beam power range, the need for non-intercepting techniques to control and diagnose such beams will motivate increased use of lasers, and the increased duty factor of such machines will motivate increases in the average power of lasers used for this purpose.

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

One 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 (e.g. a single-channel fiber amplifier chain) will be given highest priority, although proposals for individual components that offer revolutionary gains in any of the performance characteristics above, and/or in the cost per channel will also be welcomed. While Yb:fiber components are highest priority, Tm:fiber components are also encouraged.

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

b. Novel, Scalable Techniques for Carrier-Envelope Phase Locking of Multiple Fiber Lasers

Combining many fiber lasers coherently for accelerator applications will require stable locking of 10s to 100s of fiber amplifier channels to within a small fraction of an optical period. Proposals to develop a low-noise carrier envelope phase (CEP) technology that is robust, low-cost, and applicable to large numbers of fiber lasers is sought. Novel architectures employing either continuum generation or direct comb generation by optical parametric oscillator techniques to enable low-noise f-2f locking are sought. Systems must not contain any free-space optics, and priority will be given to highly integrated solutions that minimize the number of fiber connections required. Locking system must demonstrate a CEP locking performance better than 45 degrees RMS of optical phase, and a credible technology path must exist to economically achieving less than 5 degrees RMS locking performance, when measured between any two stabilized fiber lasers. Systems suitable for use at 10kHz – 100 MHz repetition rates and any near-IR fiber laser type (Yb, Er, or Tm) are sought.

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

c. 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. Candidate materials must achieve broad bandwidth (>10%), high peak power (>10 TW), and endure sustained high average power (>kW) operation. Proposals to develop new laser gain materials and/or advanced sintering techniques for producing very high quality laser gain media are sought. Proposals to develop techniques capable of producing precisely controlled spatial gain profiles are strongly encouraged.

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

d. High Reliability Arbitrary Pulse Pattern Laser Amplifiers for H- Beam Control and Diagnostics

Grant applications are sought for high reliability, variable pulse-pattern, high repetition-rate, intense near-IR lasers for neutralizing, notching, tailoring, and diagnosing H-minus beams. The primary challenges of such systems and similar to those of an industrial engraving and marking laser system, and are: (1) robustness and reliability, (2) stable operation despite arbitrary bunch patterns and widely variable output power, and (3) compactness.

In the typical application, the laser will be installed and operated in a harsh industrial environment, and will be required to operate with greater than 99% uptime. The laser must be engineered to allow reliable remote operation, requiring no more than one hands-on intervention per day to maintain operating parameters. A compact configuration (e.g. less than 1 m x 1 m x 1 m) with suitable environmental controls and EMI shielding is required.

The amplifier will be seeded by a computer-controlled external source that provides arbitrary pulse bursts at up to 60 Hz that last up to 100 microseconds, with individual pulses occurring at a rate of 500 kHz. The individual pulses are gated out of a 200 MHz pulse train that is phase-locked to an external microwave reference. Similarly, the 500 kHz and 60 Hz substructures are controlled by an external timing system and are variable. The pulse energy and pulse length are each variable, ranging up to 2 mJ in a 2 nanosecond duration flat-top micro-pulse. Up to 3000 pulses per second from the 200 MHz pulse train may be amplified to full energy, requiring an average output power of up to 6 W. Output must be to free-space, with an M-squared less than 1.5. Beam pointing jitter and divergence jitter must be minimized such that the focal spot, when relay imaged several meters away, has less than 1/10 w0 position jitter and less than 1/10 w0 diameter variation (w0 is the Gaussian waist size), irrespective of the number of pulses amplified per second.

While current applications call for very modest average power, within the next decade systems capable of much higher duty factor operation and consequently much higher average laser power (exceeding 3 kW) will be needed. Therefore, priority will be given to applications that not only meet the parameters for the first-generation systems, but can demonstrate a clear technology path to multi-kW operation over the next 5-10 years.

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

e. Aperture-Scalable High Performance Diffraction Gratings

Diffraction gratings are employed in high energy laser systems in several ways, including pump wavelength stabilization, spectral beam combining, pulse compression, and near-field spatial filtering. These components are of critical importance in enabling high average power petawatt-class laser systems. Traditional surface-etched gratings, while aperture scalable, suffer from poor diffraction efficiency and high loss. Volumetric gratings deliver high diffraction efficiencies with excellent spectral and angular selectivity, but suffer from poor uniformity when scaling to large apertures needed in high energy laser systems.

Grant proposals are sought which would enable scaling of dispersive optical elements to large apertures (greater than 10 cm x 10 cm) while maintaining excellent uniformity (<quarter wave of distortion over the active aperture), good bandwidth performance (>5% minimum, with >10% preferred), high diffraction efficiency (>95% minimum at 1 micron or >90% minimum at 10 microns), and high optical damage threshold (>0.5 J/cm2 at 1 ps or >10 J/cm2 at 1 ns). Of particular interest are technologies which enable such improvements while reducing the cost of such components.

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

f. Computer Modeling and Development of High Power Coatings for Ultrafast Optics

An identified common bottleneck for all high average and high peak power lasers for accelerator applications is the damage threshold of coatings. Grant applications are sought to increase understanding of laser damage and to develop coatings with higher damage threshold. Particular interest is in coatings suitable for femtosecond-class pulses. Designing robust optics lasting billions of shots requires the development of predictive modeling of laser damage. Developing tools to fully understand and optimize the effective pulse profile that an optic sees, and increasing the damage threshold, are critical and will have very significant benefits, including size and cost reduction of the laser systems as well as reliability and longevity.

Proposals are sought for R&D leading to ultrafast coatings supporting 10% minimum bandwidth operation with very low dispersion, very low absorption loss (consistent with minimal thermally-induced wavefront distortion at incident average power densities of 100 W/cm2), and laser damage threshold (0.5 J/cm2 minimum) for sub-picosecond pulse operation. Coating techniques must be scalable to large apertures (e.g., 10 cm x 10 cm) and coatings should be cleanable in the field by standard techniques. Wavelengths of interest are primarily in the near-IR from 0.8 microns to 2 microns, but advances in broadband high damage threshold coatings for use at 9-10 microns are also of interest.

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

g. End-to-End Systems Modeling of Large Ultrafast Laser Systems

Development and engineering of complex state-of-the-art femtosecond laser systems requires sophisticated computational design tools and predictive models. Fully integrated 4D modeling tools are needed to design and use high power laser systems for accelerator applications. An example would be calculating the pump distribution and amplified spontaneous emission (ASE) in an amplifier, calculating the effective gain distribution in the amplifier, calculating and accounting for heat loading and flow, and using the resulting gain and refractive index distributions to conduct an integrated propagation simulation for a chain of amplifiers.

Grant proposals are sought for the development of computational tools that support end-to-end design of laser systems, to include accurate modeling of pump light absorption and spatio-temporal gain modeling; calculation of ASE in unseeded and seeded amplifier chains; accurate modeling of the propagation and amplification of the seed pulse, including higher-order effects such as gain narrowing, thermal lensing, pump depletion, B-integral effects, and dispersion. While a general code capable of modeling either fiber laser systems or free-space laser systems is desired, a highly optimized solution addressing just one architecture type is also of interest.

Optional but highly desirable features include: sophisticated parametric system optimization, estimation of carrier envelope phase distortions, modeling trains of phase- and spectrally-encoded pulses, and the ability to support Raman and Brillouin scattering effects (esp. for fiber systems) in a future code release.

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

h. High Efficiency Spatial Mode Shaping and Control for High Power Ultrafast Lasers

Research on the development of laser plasma accelerators has identified laser transverse model shaping and control, to ensure high efficiency guiding in plasma channels, as one of the key challenges.

Grant proposals are sought to develop fully passive (i.e. using no adaptive optics) methods for producing high Strehl-ratio (>0.95) Gaussian-like far-field profiles from flat-top near-field profiles, for lasers in the femtosecond-class with tens of Joules of pulse energy. Simplicity, robustness, and cost are key considerations of such a mode shaping system. Interest is primarily for Ti:Sapphire systems, but mode shapers suitable for ultrafast high energy Tm lasers are also of interest.

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

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26. 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 STTR Phase I 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 and Cable 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 production of a sufficient amount of material (1 km minimum continuous length) for winding and testing cables and subscale coils.

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 concurrent 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 interest for final cooling of a muon beam prior to acceleration and injection into a collider storage ring, but 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 Cavities

Grant applications are sought to develop:

(1) new SRF cavity designs with reduced RF frequency sensitivity to the Lorentz-force detuning and helium bath pressure fluctuations. (2) New SRF cavity designs for operation with high current beams. The cavity should provide efficient high-order mode extraction while not sacrificing good SRF performance. The goal of the new designs is to achieve higher-order mode loaded quality factors in the 102 – 103 range for circular accelerators and 103 – 104 range for linacs. (3) New fabrication and processing techniques for niobium cavities to reduce the cost and improve quality factor and accelerating gradient (e.g., improved welding technique, hydro-forming, doping, etc.) along with new materials for SRF cavity manufacturing. RF components for SRF cavities. (4) New cost-efficient and improved reliability designs of high-power input couplers in the frequency range of 325 MHz to 1.3 GHz. (5) High-quality low and medium-power RF components for SRF cavity tests (directional couplers, circulators, etc.) and cavity tuners including fast tuners providing wide tuner range (10-3). (5) SRF cryomodule diagnostics that aid in preserving the high performance achieved by SRF cavities during vertical tests throughout the SRF cryomodule assembly, commissioning and operation. (6) New and improved methods for cavity diagnostics in a cryomodule, including in situ Q0 measurements inexpensive sensors for residual magnetic field measurements at cryogenic temperatures, novel sensors for helium pressure, flow, and level based on fiber optics or other technologies, vibration sensors in a cryogenic environment, distributed radiation and dark current/field emission sensors using fiber optics at cryogenic temperatures. (7) In situ cleaning of SRF cavities inside the

cryomodule, to mitigate field emission on both niobium and Nb3Sn cavities. Plasma cleaning is of interest since it is already proven to be effective as an in-situ technique of cleaning the cavity surface from organic contaminants. Methods to improve the plasma cleaning technique to remove field emitters of different nature, as for example metallic flakes, are of interest. Techniques capable to mitigate field emission in-situ in the cryomodules are needed to ensure high accelerating gradients in modern and future machines.

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

d. Ancillary Technologies for Superconducting Magnets

Grant applications are sought for development of either new types of epoxies or modifications to existing baseline epoxies (e.g. CTD-101K) used in magnet impregnation with improved thermal properties, especially higher epoxy specific heat and/or thermal conductivity, which can significantly benefit the operation of superconducting magnets. In addition to thermal properties after curing, a qualified impregnation epoxy must meet several criteria:

- The capability to fill many sub-millimeter voids inside a magnet. This is usually associated with low viscosity, long pot life and wetting of the surfaces of other components (metal and fiber glass insulation)
- Cryogenic compatibility. The epoxy must be free of major cracking after cooling to the operation temperature (1.9 – 77 K) and retain mechanical strength at cryogenic temperature.
- Chemical compatibility with other components in the magnet.
- Radiation resistance. This is required for magnets that are exposed to radiation, such as those used in high energy particle colliders.

Grant applications are also sought for development of novel ideas aiming to improve stability of Nb3Sn superconducting wires and cables for accelerator magnets.

Grant applications are sought to develop new high-pressure electrical insulation and coil fabrication technology for superconducting magnets that result in less stress sensitivity and reduced quench degradation.

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

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27. 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 STTR Phase I 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 (LHC; see www.cern.ch) or potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand dark energy, 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 and for the wider HEP community. 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. DOE also expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry.

Grant applications are sought in the following subtopics:

a. Special Purpose Integrated Circuits for Detectors at High Energy Colliders

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 (hundreds of Mrad) radiation tolerance. We are interested in IP blocks and design methodologies that are compatible with radiation hardness and other special requirements (see subtopic e). 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 ICs 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 Large Cryogenic Detectors

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 liquid argon or liquid xenon 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 (see also subtopic e). Development and testing digital library timing files for sub-micron integrated circuit processes at temperatures well below -100C is of interest. Design and characterization of digital library parts in a 65nm CMOS process for long lifetime at temperatures well below -100C are of interest.

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

c. Custom Real Time Massively Parallel Trigger Processors for Detectors at High Energy Colliders

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 Detectors at High Energy Colliders

Detector data volumes at the HL-LHC will be nearly 100 times more than today. Single subdetectors will have to transmit 10s to 100s 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. Free-space/Visible Light Communication (VLC) is also of interest.

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 10m. 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 up 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 doses of hundreds of Mrad. 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.

VLC systems should have bandwidth in excess of 1Gbps, produced from radiation-hard, commercially available components and with high reliability and low cost.

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

e. Digital Processing IP Cores for Detectors in Extreme Environments

With increasing luminosity, rates, and segmentation, future detectors will require more and more real-time processing to efficiently aggregate data, extract information, reduce, re-format and transmit data performed at an early stage of the signal processing chain. Part of the digital processing nowadays performed in FPGA-based discrete electronics and external processors will be required to be performed in the front-end readout sections, embedded in System-on-Chip (SoC) Application Specific Integrated Circuits (ASICs) with robust high speed transceiver links. HEP detectors are generally operated in extreme environments in the presence of high radiation in the hundreds of Mrad or extreme temperatures down to 80K. Efficient Digital Signal Processing (DSP) programmable core implementations in suitable technologies, the required control blocks and high speed transmission links, capable to reliably operate in such environments are required in the form of IPs readily available for the scientific community.

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

f. High Density Chip Interconnect Technology

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

g. Radiation Hard CMOS Sensors for Detectors at High Energy Colliders

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

h. 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 hundreds 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. New devices with special implants for achieving gain within the sensor are of interest. In particular, methods to improve the production yield and fill area of large-area Low-Gain-Avalanche Detectors (LGADs) are of interest.

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

i. **Technology for Post-Processing of Junctions for CMOS and CCD Sensors**

Monolithic Complementary Metal Oxide Semiconductor (CMOS) Sensors have the potential to provide reduced noise, improved radiation hardness, and reduced cost compared to hybrid sensors for elementary particle physics detectors. Several foundries provide CMOS technology that is compatible with sensor integration. A similar situation exists for Charge-Coupled Devices (CCDs), which are used in astrophysics and direct dark matter detection. The optimum sensors are fully depleted high resistivity devices, which require a backside junction. Many applications also demand a very thin entrance window junction. The foundry processes, however, do not provide double sided processing. Adding the junction after the CMOS processing has been completed is problematic, because the temperature necessary to activate the dopant would damage the CMOS or CCD structure on the front side. Proposals are sought for novel, robust, cost-effective process technologies to enable backside junction activation at temperatures below 400 C, and that are compatible with post-foundry substrates and both CCD and CMOS sensors. MBE and laser anneal technologies are specifically excluded from this call.

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

j. **Direct Wafer Bonding Techniques to Build Up Very Thick Sensors**

Proposals are sought for technologies to increase the active mass of semiconductor-based dark matter detectors. Current devices are based on silicon or germanium wafers with either charge coupled devices, CMOS imagers, or transition edge sensing elements. Direct wafer bonding technologies have the potential to increase detector mass by attaching additional layers of active material and build up ~5mm thick sensors. This could be done as a direct Si-Si bonding operation, or could use an oxide bonding with a patterned array of pores to allow the charges through while reducing charge cloud dispersion for finely segmented detectors. Proposed work may include bonding of existing silicon structures to additional layers of high resistivity material to demonstrate yield and charge transfer efficiency; it could utilize existing structures (e.g., pad or strip silicon detectors) to demonstrate successful bonding, top metal application, and operation.

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

k. **Radiation Hard, Low Mass IC Power and High Voltage Delivery Circuits for Detectors at High Energy Colliders**

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 are 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

l. **Frequency Multiplexed DAQ Systems Motivated by Cosmic Microwave Background Detectors**

Future CMB experiments will have large focal plane arrays with ~500k 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

m. Ultra-low Noise DAQ Systems Motivated by Rare Event Detectors

New Direct Detection Dark Matter detectors and Coherent Neutrino Scattering detectors must reach eV-level sensitivity for recoil energy detection. Detector candidates such as skipper CCDs can achieve <0.1 electrons of noise and detect nuclear and electron recoils of few eV. Large DAQ systems will be needed with the requirement of adding negligible noise to the detector system. The number of channels needed could reach 20,000 in the next 10 years. The data volumes can be as large as 10 GB/s.

Grant applications are sought to develop ultra-low noise detector and DAQ electronics. The detector electronics may additional requirements such as radio-purity and the ability to work at cryogenic temperatures and in vacuum. The DAQ must maintain the ultra-low noise in an integrated system, with potential noise sources from AC lines and vacuum and cryogenic systems connected to the detector.

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

n. Electronic Tools for Picosecond (ps) Timing

High precision timing measurements in next generation detectors will require the development of circuitry to measure time to 1 ps or better, to digitize waveforms at above 10Gs/s. In addition, a method to distribute a stable reference clock with jitter of 5 ps of less and precise frequency stabilization is needed. Such a clock system needs to distribute the clock to multiple detector components distributed by distances of order ten to twenty meters. Custom radiation-hard ASIC devices will eventually be needed for many such high precision uses, but non-radiation hard demonstration systems meeting ps or sub-ps sensitivity and stability are of immediate interest.

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

o. 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, 2015, La Biodola, Isola d'Elba, Italy. https://indico.cern.ch/event/359839/

5. International Conference on Technology and Instrumentation in Particle Physics 2017 (TIPP2017), 2017, Beijing, China. http://tipp2017.ihep.ac.cn/

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

7. 14th Vienna Conference on Instrumentation, 2016, Vienna, Austria. http://vci2016.hephy.at/de/home/

28. 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 STTR Phase I 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 (LHC; see www.cern.ch) or potential future High Energy Colliders, 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 and for the wider HEP community. 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. DOE also expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry.

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 (ps) Timing Particle Detectors

Charged particle detector systems that would affordably cover large areas of tens of m^2 with time resolutions in the range of tens of ps and fine segmentation at the cm to sub-mm level have applications for all three research frontiers. Areas of interest are developments that would improve the particle rates of up to MHz/cm^2, that would reduce cost via use of commercial batch production, that could provide resolutions ranging down to 10 microns in space and/or 1 psec in time are of interest, and that would successfully demonstrate sensor elements of order 50 cm^2 or larger with uniform performance.

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 500,000 bolometers. Several fabrication processes are needed to enable such large scale detectors, and can also be applicable to other experiments.

- Sub-kelvin (10-50mK 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 (tens of Mrad), fast (tens of nano-second) scintillators and wavelength shifting materials is of particular interest to the colliding beam community. Development of fast (tens of nano-second), wavelength-matched shifting materials is of interest for liquid argon and liquid xenon detectors for neutrinos and dark matter. Brighter, faster, radiation-hard 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 (~500kV) 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 for efficient operation of high purity multi-kiloton cryogenic noble liquid systems are needed.

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

i. Ultra-Low Mass, High-Rate Charged Particle Tracking

Some high intensity experiments searching for very rare phenomena, such as neutrino-less coherent muon-to-electron conversion and muon decays to e+e-e- or to e- gamma, require precision charged particle tracking at low momenta in the 10 - 100 MeV/c range. Momentum resolutions of 0.1% are required in order to mitigate steeply falling physics backgrounds, necessitating ultra-low mass designs. Improvements in sensitivity beyond currently planned experiments require the development of technologies capable of achieving the necessary resolutions while operating in vacuum and handling average rates of order 10 kHz/cm^2 with peak rates approaching 1 Mhz/cm^2. The envisioned tracking systems are modestly sized, providing coverage over areas of order 10 m^2.

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

j. Additive Manufacturing

Detectors for particle physics are often characterized by large areas or large volumes, need exquisite performance and need to be composed of materials that have to withstand harsh conditions, such as ultra-cold, high pressure or high-radiation environments. Additive manufacturing holds the promise to fabricate sensors and detectors that meet the stringent requirements of particle physics experiments in a cost-effective and tailored manner. Proposals are sought in this area that address the specific needs of the experiments.

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

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29. QUANTUM INFORMATION SCIENCE (QIS) SUPPORTING TECHNOLOGIES

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

Quantum science and instrumentation for next-generation computing, information, and other fields—the core of "quantum information science" (QIS)—are developing rapidly and present numerous opportunities for impacts in high energy physics. Quantum sensors and controls, analog simulation, and qubit systems that specifically rely on or exploit superposition, entanglement, and squeezing of physical states are of particular interest. This topic focuses on key technologies to support quantum information systems that build on experience in high energy physics experimental systems, and on further development of quantum information systems for application in precision measurement, simulation, and computation that advances high energy physics research.

Grant applications are sought in the following subtopics:

a. Development of Optimal SRF Cavity Geometries for Quantum Information Systems
One promising architecture for quantum computing involves superconducting Josephson-junction-based qubits enclosed by superconducting 3D microwave resonators, currently providing the longest coherence times among all superconducting qubits. Achieving the highest possible quality factor Q of the host resonators is one of the identified high impact directions for improving the coherence time of the cavity-qubit systems, as the superconducting resonator serves as a “shield” to isolate the qubit from environmental de-coherence. Furthermore, high-Q cavities have been proposed as possible “quantum memories” where information about the quantum state can be stored during computations. A typical frequency range for superconducting qubit operation is 6 GHz to 15 GHz. 3D niobium SRF cavities, similar to those used in particle accelerators, should be able to provide high quality factors in this frequency range. However, existing cavity geometries are optimized for particle acceleration rather than hosting qubits. Grant proposals are sought for development of 3D SRF cavity geometries in the frequency range of 6 GHz to 15 GHz for hosting superconducting Josephson-junction-based qubits. The geometries should be suitable for scalability from a single SRF cavity-qubit unit to multi-qubit systems.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

b. Optimization of Fabrication Techniques for Scalable 3D SRF Structures for Quantum Information Systems
Traditionally, 3D niobium SRF cavities for particle accelerators are fabricated using electron beam welding of stamped/hydro-formed parts. This approach works well at frequencies below 3.9 GHz. However, future quantum information science (QIS) systems will likely operate in the frequency range of 6 GHz to 15 GHz and will consist of many individual cavity-qubit units coupled together. It is very important to re-assess the cavity fabrication and develop new techniques suitable for high-frequency, scalable SRF structures for QIS. An example of such technique could be precise machining of split-cell-like structures. Grant proposals are sought to develop cavity fabrication techniques optimized for scalable 3D SRF structures for QIS.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

c. Development of Low-Temperature Technologies for QIS Systems

QIS systems operating below one Kelvin (1 K) are growing in scope and cold mass, and potentially include next generation cosmic microwave background (CMB) detectors, dark matter search detectors, some qubit systems for quantum computing, and other quantum sensor technologies operating in the milli-Kelvin (mK) range. Grant proposals are sought for the development of: (1) 4He/3He hybrid refrigeration systems that can efficiently sink power at both 1 K and mK temperatures, likely requiring separating the dilution refrigerator circuit from a separate 1 K cryogenic system; (2) High Density Interconnect (HDI) cables for microwave and RF readouts (frequencies ~1 – 10 GHz) operating with high bandwidth and low thermal loss at mK temperatures that transition to 1 K temperatures; (3) low-power mechanical actuators that can operate at mK temperatures with low thermal loss; (4) low-noise electrical circuit switches operating at mK temperatures with injected noise at the few-quanta noise level.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

d. Photodetectors for Optical to Microwave Transduction of Quantum Information

Improvements in microwave detection can be applied to cosmic microwave background and axion detection, and may be enabled by QIS-based approaches. While substantial quantum squeezing can be produced optically, the ability to write that information onto microwave photons in a cavity would enhance the readout of microwave detectors. With improvements in transduction of quantum information, entanglement could also be distributed among many distant microwave resonators to create a very large sensor network (using entangled photons). Grant proposals are thus sought for production, testing, and/or validation of photodetector systems with high speed (>5GHz) and quantum efficiency (>95%) for the purposes of detecting continuous variable quantum information and writing it onto microwave photocurrents that are compatible with microwave cavities.

Questions – Contact: Altaf Carim, altaf.carim@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: Altaf Carim, altaf.carim@science.doe.gov

References:

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PROGRAM AREA OVERVIEW – OFFICE OF NUCLEAR ENERGY

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, proliferation resistance, and security barriers through research, development, and demonstration as appropriate.

NE's programs are guided by three priority focus areas:

(1) Maintaining the current nuclear reactor fleet;
(2) Encouraging growth for a new advanced reactor pipeline (both near- and longer-term), including through the employment of key private-public partnerships; and,
(3) Redeveloping America's nuclear fuel cycle, infrastructure, and supply chain.

Nuclear energy is a key element of United States (U.S.) energy independence, energy dominance, electricity grid resiliency, national security, and clean baseload power. America's nuclear energy sector provides over 60 percent of the nation's annual clean electricity production, generates nearly 20 percent of U.S. electricity from a fleet of 99 operating units in 30 states, supports 500,000 jobs, and contributes $60 billion per year to our Gross Domestic Product (GDP). America's nuclear energy sector also plays key national security and global strategic roles for the U.S., including nuclear nonproliferation.

The Office of Nuclear Energy's SBIR/STTR workscopes also support the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative (see https://gain.inl.gov), which provides the nuclear energy community with access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet.

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 STTR Phase I 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; innovative digital technology for use in improving monitoring and control of nuclear energy systems; enable the development of advanced power reactor designs; and facilitate development and implementation of advanced fuel cycle technologies.

Technology should demonstrate greater accuracy, reliability, resilience, higher resolution, and ease of replacement/upgrade capability for applications in the nuclear environment and also reduce operations and maintenance costs and address regulatory concerns.

The selected technology should support the Gateway for Accelerated Innovation in Nuclear (GAIN) Initiative and be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting.

Applications are sought in the following areas:

- Sensors using advanced manufacturing techniques that can be qualified and applied to process measurements needed for nuclear energy systems and their anticipated service environments. Of high interest are multimodal sensors/sensor networks capable of simultaneous measuring more than one parameter and sensors/sensor networks incorporating inherent common cause failure resistance by measuring parameters via more than one physical signal. Sensors and instrumentation to generate data needed to support improved plant control and data analytics applications for improved plant operations.
- Digital monitoring and control systems that increase nuclear plant system reliability, availability, and resilience including the ability to detect and manage faults in I&C systems and plant components; state of the art control rooms, control systems, and plant control technologies, including automated work management systems; and big data analytics and applications to improve plant operation and control.
- Nuclear Plant Communication technologies that securely and reliably support greater data generation and transmission demands expected to accompany advancements in digital sensor, measurement, and control technologies. This may include power harvesting, energy storage, data transmission techniques, and related methods to reduce both power cabling and communication cabling needed for sensors and communications in I&C systems.
- Development of technologies to enable use of advanced instrumentation for severe environments (including the high temperature, high pressure, high radiation environment expected for transient testing). This could include technologies for compact form factor, leak-tight fiber optic pressure-vessel feed-through systems for multiple fiber sealing and/or development of small form factor, wide field-of-view, high frame-rate, high-resolution, infrared/optical boroscope or other video probe technologies.

Grant applications that address the following areas are NOT of interest for this subtopic and will be declined: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; 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, with current emphasis on Accident Tolerant Fuel program needs, 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 and lead fast reactors. Specific technologies that improve the safety, reliability, and performance in normal operation as well as in accident conditions are desired.

- Provide new innovative LWR fuel concepts, to include fuel and/cladding, with a focus on improved performance (especially under accident scenarios), and with a priority on ceramic cladding and novel pellets. 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.
- Develop advanced automated, accurate, continuous vs. batch mode process techniques to improve TRISO particle fueled-pebble manufacturing to include: (a) improved fabrication methods for isostatic pressing of pebbles for TRISO pebble bed-fueled reactors using advanced automated fabrication to replace manual manufacturing techniques, and (b) advanced methods for non-destructive evaluation testing of TRISO-fueled pebbles.
- 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 declined: thorium 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. Energy Advanced Modeling & Simulation for Nuclear Energy Innovation Hub for Modeling and Simulation

High-fidelity computational simulations using Virtual Environment for Reactor Analysis (VERA) provide predictive capabilities for the design and performance assessment of light water reactor core and fuel assembly designs. Predictive simulations are computationally intensive, requiring high performance computing resources for time dependent analysis. In order to make the insights that may be gained from these simulation capabilities more accessible to vendors and operators, we are seeking grant applications for development of a reduced-order, physics-based, real-time simulator built on a foundation of the VERA-CS analysis capability. Desired software development includes but is not limited to:

- Development of a fast-running desktop-scale reactor core simulator environment that can provide real-time simulations of desired conditions and time sequences. This physics-based simulator needs to be able to be calibrated or calibrate itself to time-dependent VERA simulation data for the specific nuclear plant technology for which the simulator is created.
- Development of a real-time control-room environment simulator using VERA as the underlying physics driver.

Questions – Contact: Tansel Selekler, Tansel.Selekler@nuclear.energy.gov

d. Modeling and Simulation (NEAMS)

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, but these advanced tools often require large computational resources, can be difficult to install, and require expert knowledge to operate. It is desirable to enhance the NEAMS Workbench (see B. T. Rearden, et al, "Introduction to the Nuclear Energy Advanced Modeling and Simulation Workbench," M&C 2017–International Conference on Mathematics & Computational Methods Applied to Nuclear Science and Engineering, Jeju, Korea, April 16–20, 2017), in order to integrate robust multi-physics capabilities and current production tools for ease-of-use and deployment to end users, and for enabling the use of high-fidelity simulations to inform lower-order models for the design, analysis, and licensing of advanced nuclear systems and experiments.

Grant applications are sought that:

- Facilitate the incorporation of codes used, or likely to be used by the advanced reactor industry (in addition to NEAMS developed codes) into the NEAMS Workbench
- Facilitate access to advanced modeling and simulation tools for inexperienced users, such as automated generation of finite element meshes, especially hexahedra meshes, from CAD or combinatorial solid geometry models;
- Facilitate workflow management between legacy physics software commonly used in nuclear engineering practice and modern high-fidelity codes that are more predictive but incur a higher computational cost. It is desirable to integrate consistent workflows where a user can select physics modules of differing fidelity and have a workflow manager transfer data from one tool to the next, enabling a user to choose among multiple high- or low-fidelity tools for each type of physics in a multiphysics simulation.
- Apply the results of high-fidelity simulations to inform the improved use of lower-order models for improved use of fast-running design tools; and
- Provide capabilities for automated verification of numerical solutions, including mesh refinement studies.

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

e. TECHNOLOGY TRANSFER OPPORTUNITY: Risk-Informed Safety Margin Characterization (RISMC) EMRALD 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 (user interface, 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 ensure leveraging of the Government investment in the initial software development. Proposals targeting the steps needed to bring probabilistic software applied by 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 the software called the Event-Modeled Risk Assessment using Linked Diagrams (EMRALD) which is part of the RISMC tool kit. EMRALD is a dynamic risk analysis tool based on a discrete event simulation, where the user can model complex systems in a probabilistic manner based upon a state-diagram approach. The EMRALD software was originally developed for time-dependent risk analysis, recently this tool has been leveraged to couple with 3D flooding simulations. Also, it has been successfully demonstrated to be able to couple seismic, flooding, and thermal-hydraulics calculations into an integrated analysis platform. Capabilities in enhancing the model development process via a graphical interface, including browser-based technologies, are of interest. The proposal should also demonstrate that the proposer has the necessary technical and business aspects to develop any proposed code modification to EMRALD (e.g., improved graphical user interface) and to manage the code commercialization process.

Licensing Information:
Idaho National Laboratory Information
Contact: Arthur L. Baker, arthur.baker2@inl.gov , 208-526-1872
License type: Nonexclusive
Software Copyright

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

f. Component Development for Energy Conversion Systems to Support Nuclear Power Systems

Opportunity Description:
DOE is seeking proposals for collaborative small business partnerships from a U.S. company or companies to advance both the sCO2 and other types of Brayton power cycle systems and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- High temperature Seals and Bearings
- Ceramic based Bearing/Seal technology
- Advancement of Pressure Activated Leaf Seals (PALS)
- Thermal management of SCO2 turbomachinery
- Strengthened materials to prevent erosion in Turbomachinery
- Turbomachinery development for 900C operation
- Advanced cooling techniques for low temperature sCO2 bearings and seals being implemented in high temperature systems
- Thermal tuning of sCO2 turbine inlet conditions
- Advanced filtration in sCO2 with low pressure drop filters
- Piping systems to accommodate 900C conditions
- Waste heat recovery using sCO2 Brayton cycles with diesel gen sets
- Hermetically Sealed Torque Couplers
- Electro-Dynamic Magnetic Bearings
- Additive Manufacturing of turbines and compressors
- Fast response throttle, bypass, and stop valves
- Ceramic PCHEs
- Cast material heat exchangers
- Fast Response Magnetic bearings
- Dry heat rejection
- Scalable sCO2 mass flow meters, state of health monitors, smart control systems with remote monitoring for unattended operation
- Technology to reduce overnight cost to less than $900/Jee

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

g. Advanced Methods for Manufacturing

A strong manufacturing base is essential to the success of the U.S. reactor designs currently competing in global markets. In addition, 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. This workscope also supports the Department of Energy's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative which provides the nuclear community with access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization. The initiative also helps to ensure the continued safe, reliable, and economic operation of the existing nuclear fleet.
Applications are sought in the following area:
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:

- methods to improve the process, speed, quality and cost of welding and the required in-process and post welding inspections
- methods and processes to fabricate components using advanced technologies like 3D printing forms of additive manufacturing processes that can eventually produce nuclear quality components.
- expanded or improved non-destructive examination (NDE) methods for components produced using additive manufacturing techniques
- methods that can improve the manufacturing processes required for the development of pressure vessels for a TREAT irradiation vehicle using Inconel-718 through additive manufacturing process that meets ASME requirements. If required, heat treatment process specifications should be developed and associated mechanical properties data produced to allow for production and use of the component for applications meeting ASME pressure boundary requirements.

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

h. Nuclear Energy Cyber Security

Current operating nuclear power plants, research reactors, and fuel cycle facilities are designed and built with purely analog instrumentation and control systems. Due to multiple technical, regulatory, and operational requirements, many of these facilities are progressing towards the adoption of digital controls, especially in balance-of-plant systems. In addition, next generation nuclear power plants, including those under construction or in early stages of design, include digital control systems to monitor plant conditions and control plant functions. The benefits of digital control systems are accompanied by costs and risks from potential cyber vulnerabilities. In recognition that there are unique technology challenges relevant to risk management for nuclear energy systems, DOE's Office of Nuclear Energy supports the research, development, demonstration, and deployment of technical products and solutions that enable nuclear facilities to implement digital technologies while cost-effectively preventing, detecting, and mitigating cyber threats to nuclear energy systems.

Grant Applications are sought in the following subtopics:

- Insider Threat Cyber Risk Management - development of an innovative tool or methods that designers or operators can utilize to detect, characterize, and/or prioritize engineering or operational responses to an insider cyber threat.
- Supply Chain Cyber Risk Management - development of an innovative tool or methods to establish a designer's or operator's confidence in a cyber resistant supply chain.
- Secure Architectures – development of cyber-informed engineered components or systems that are compatible with secure digital control system architectures. Design features should optimize the implementation of licensable, engineered barriers against cyber attack while maintaining a plant's reliability and cost effectiveness.
- Modeling & Simulation - development of modeling and simulation tools of cyber-physical phenomena for equipment or systems within a complex nuclear facility environment. The capability should support development of cyber-informed designs through emulating a component's or system's capability to detect and respond to a simulated cyber event.
- 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 descriptions above.

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

References: Subtopic a-i:

1. United States Department of Energy Office of Nuclear Energy, Homepage. http://energy.gov/ne/office-nuclear-energy

2. United States Department of Energy Office of Nuclear Energy, 2010, Nuclear energy Research and Development Roadmap, Report to Congress. https://energy.gov/sites/prod/files/NuclearEnergy_Roadmap_Final.pdf

3. United States Department of Energy Office of Nuclear Energy, Fuel Cycle Research and Development Program. https://energy.gov/ne/fuel-cycle-technologies/fuel-cycle-research-development

4. Idaho National Laboratory, 2010, Technical Program Plan for INL Advanced Reactor Technologies Technical Development Office/Advanced Gas Reactor Fuel Development and Qualification Program, Rev. 6, INL/MIS-10-20662. https://art.inl.gov/trisofuels/Lists/References/Attachments/44/PLN-3636_rev_6.pdf

5. Petti, D., Bell, G., et al, 2005, The DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program, 2005 International Congress on Advances in Nuclear Power Plants, INEEL/CON-04-02416. https://inis.iaea.org/search/search.aspx?orig_q=RN:39005010

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2. Idaho National Laboratory, 2014, Light Water Reactor Accident Tolerant Fuel Performance Metrics, Advanced Fuels Campaign, INL/EXT-13-29957 http://www.osti.gov/scitech/servlets/purl/1129113

3. Idaho National Laboratory, 2013, Advanced Fuels Campaign 2013 Accomplishments Report, INL/EXT-13-30520 http://www.osti.gov/scitech/servlets/purl/1120800

4. Idaho National Laboratory, 2014, Advanced Fuels Campaign 2014 Accomplishments Report, INL/EXT-14-33515 http://www.osti.gov/scitech/biblio/1169217

5. Idaho National Laboratory, 2015, The Mission and Accomplishments from DOE's Fuel Cycle Research and Development (FCRD) Advanced Fuels Campaign, Top Fuel 2015, INL/CON-15-34947 http://www.osti.gov/scitech/servlets/purl/1236849

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 STTR Phase I Applications: YES

The US DOE Office of Nuclear Energy, Office of Spent Fuel and Waste Science and Technology is conducting research in long-term storage, transportation, and eventual disposal of spent nuclear fuel (SNF). Storage of SNF is occurring for longer periods than initially intended; therefore, it is desirable to assess technical performance issues of the SNF storage systems and transportation systems after extended durations. In the area of SNF disposal, research is directed toward generic repository disposal systems in argillite, salt, and crystalline rock.

Grant applications are sought only in the following subtopics:

a. Repair and Mitigation of Cracks in Spent Nuclear Fuel Storage Canisters

The possibility of stress corrosion cracking (SCC) in welded stainless steel dry storage canisters (DSC) for spent nuclear fuel (SNF) has been identified as a potential safety concern. The canister fabrication welding procedure introduces high tensile residual stress and microstructure sensitization in the heat-affected zone (HAZ), which might drive the initiation of pitting and/or the transition to SCC growth when exposed to an aggressive chemical environment. Analysis of samples surface-deposited on in-service DSCs at three near-marine independent spent fuel storage installation (ISFSI) sites have demonstrated the presence of chloride-rich salts on the outer canister surfaces. As portions of the canister surfaces cool sufficiently, the marine atmospheric salts might deliquesce and generate an aqueous brine layer on the surface of the canisters at various locations. This aggressive environment could lead to pitting, SCC, and potentially a through-wall failure in the weldments of the canisters.

To prevent the potential for a through-wall crack, it is necessary to develop repair and mitigation technologies for the identified pitting and cracks. The main incentive for development of repair technology is to avoid the enormous cost of canister replacement, and significant safety related issues during the replacement process. Cost-effective repair technologies would promote the continuation of long-term safety performance of DSCs at ISFSIs. Both the repair and mitigation techniques must be capable of in-service repair on loaded systems, which requires low heat input, no spark source, and acceptable external forces to avoid significant reduction in mechanical strength, ignition of potential hydrogen gas inside the canister, and deformation of the canister during the repair process. Development of crack repair techniques using novel welding repair technologies in combination with mitigation technologies to prevent or minimize future pitting or SCC would be useful to maintain and/or restore the mechanical integrity of the DSCs under extended service conditions.

Potential repair techniques include polymer cold welding, and additive friction stir welding (FSW) technology. Such technologies could potentially introduce compressive residual stress to the surface of the components or canisters, which might suppress the possibility of future crack initiation. The lower heat input would also avoid or mitigate the microstructure sensitization, which would further suppress the susceptibility to SCC and thus contribute to the long-term safety performance of the canisters. Potential mitigation techniques include peening or burnishing of the welds (the original fabrication welds, or the subject repair welds, or both) to reduce tensile stress or coatings or inhibitors to minimize corrosion are of interest.

Questions – Contact: John Orchard, John.Orchard@doe.gov

b. Understanding Engineered and Natural System Barriers for Repositories

Assessments of nuclear waste disposal options start with the degradation of waste forms and consequent mobilization of radionuclides, reactive transport through the near field environment (waste package and engineered barriers), and transport into and through the geosphere. Science, engineering, and technology improvements may advance our understanding of generic deep geologic environments (e.g., argillite, salt, or crystalline rock geologic repository) and will facilitate the characterization of the engineered and natural barriers and better enable analysis of expected performance during the post-closure period. DOE is required to provide reasonable assurance that the disposal system contains and isolates the waste for an extended time period (i.e., engineered and natural systems work together to prevent or delay migration of waste components to the accessible environment).

DOE invites proposals involving novel materials, testing methods, and modeling concept and capability enhancements that support the program efforts to design, develop, and characterize the barrier systems and performance (i.e., to assess the safety of a nuclear waste repository). DOE will consider proposals addressing applications of state-of-the-art uncertainty quantification and sensitivity analysis approaches to coupled-process modeling and performance assessment contributing to a better understanding of barrier system performance and the optimization of repository performance.

Research proposals are sought to support the development of materials, modeling tools, and data relevant to permanent disposal of spent nuclear fuel and high-level radioactive waste for a variety of generic mined disposal concepts in argillite, salt, or crystalline rock. Key contributions may include one or more of the following:

- Improved understanding of the degradation processes for engineered barrier materials (i.e., waste containers/packages, buffers, seals) under evolving repository thermal conditions and radionuclide transport processes through these materials leading to and including the development of improved models to represent these processes.

- Development of new techniques for in-situ field characterization of hydrologic, mechanical, and chemical properties of host media and groundwater in an excavated tunnel.
- Development of new and innovative concepts (in different geologic media – argillite, salt, or crystalline rock) for sealing repository openings (e.g., shafts, tunnels, wells) to facilitate repository closure and provide required long-term waste isolation and performance.
- Identification and assessment of novel buffer materials, state-of-the-art tools and methods for passive characterization and monitoring of engineered system component properties and failure modes.
- Other innovative or novel proposals with potential to advance understanding of materials or systems, characterization, monitoring, and / or performance of engineered and natural system barriers and their capability to isolate and contain waste may also be considered by the department.

Questions – Contact: Mark Tynan, Mark.Tynan@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: John Orchard, John.Orchard@doe.gov

32. NUCLEAR SCIENCE USER FACILITIES

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

The Nuclear Science User Facilities (NSUF) is one of a diverse number of U.S. Department of Energy (DOE) user facilities established to provide researchers with the most advanced tools of modern science. NSUF is the DOE Office of Nuclear Energy's (DOE-NE) first and only sponsored user facility, and is singularly focused on advancing technologies supporting nuclear energy applications. The NSUF is fairly unique in that it is not formed from a single self-contained facility but represents a consortium of facilities distributed across the U.S. at a number of institutions. The NSUF is centered at and managed from the Idaho National Laboratory (INL), where it was originally founded. NSUF partner facilities include eight universities, plus the three Idaho universities that are part of the Center for Advanced Energy Studies (CAES), four national laboratory facilities, and one industry facility. Inclusion of additional partner facilities as well as international affiliations is anticipated in the future.

The NSUF goal is to produce the highest quality research results that will increase understanding of advanced nuclear energy technologies important to DOE-NE and support national priorities by adapting to the needs of DOE-NE programs, industry, and new innovative concepts. The core mission of the NSUF is to provide the nuclear energy researchers with no-cost access to its specialized and often unique R&D capabilities. Through this process, the NSUF program fosters the development of novel ideas provided by external contributors from universities, national laboratories, and industry while promoting collaborations between those contributors and the expertise associated with the NSUF partner capabilities. These collaborations define the cutting edge of nuclear technology research in high temperature and radiation environments, contribute to improved industry performance of current and future nuclear reactor systems, and stimulate cooperative research between user groups conducting basic and applied research.

Grant applications are sought in the following subtopics:

a. Development of Advanced Concepts for Remote Mechanical Testing of Highly Irradiated Materials

Grant applications are sought to adapt existing or develop novel mechanical testing capabilities for use in a high-radiation environment in a hot cell. The equipment would have to be able to withstand a high-radiation environment as well as be remotely operated in all stages of the test as well as system installation, calibration, cleaning and repair.

Particular interest is in the ability to test small sample sizes (sub ASTM E8).

One potential location for this capability is the Hot Fuel Examination Facility (HFEF) at the Idaho National Laboratory (INL). HFEF is one of the largest hot cells dedicated to radioactive materials research at INL. The nation's lead laboratory for nuclear energy research and development utilizes HFEF capabilities for remote handing of highly irradiated materials to support research and development of safer and more efficient fuel designs and to evaluate material performance after irradiation. HFEF has two large, highly shielded hot cells with handling and loading facilities capable of receiving large shipping casks and fuel assemblies up to 12 feet long. The main cell, which is stainless steel-lined and gas tight, has 15 workstations, each with a 4-foot thick window of oil-filled, cerium-stabilized glass and a pair of remote manipulators.

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

b. Development of Resistance Welding Capability

Grant applications are sought to develop advanced joining capability in the area of resistance welding. Resistance welding is a thermo-electric process in which heat is generated at the interface of the parts to be joined by passing an electrical current through the parts for a precisely controlled time and under a controlled pressure (also called force). To leverage NSUF's investments, we are seeking to add a resistance welding system to NSUF's capabilities.

As the nation's lead nuclear energy laboratory, Idaho National Laboratory is committed to a) accelerating innovation in nuclear energy manufacturing (part of the GAIN initiative – Gateway for Accelerating Innovation in Nuclear) and b) deploying the world's first SMR in Idaho. INL is partnered with several companies, including NuScale, TerraPower, GE, Premier Technologies, and others) to achieve this objective. INL is building capabilities for advanced joining technologies that support these corporate partners who are investing in this area.

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

References:

1. Nuclear Science User Facilities, Home Page. https://nsuf.inl.gov/