U.S. Department of Energy

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

Topics

FY 2023

Phase I

Release 1

Version 3, August 3, 2022

- Office of Advanced Scientific Computing Research
- Office of Basic Energy Sciences
- Office of Biological and Environmental Research
- Office of Nuclear Physics

Schedule

The Congressional authorization for the SBIR and STTR programs is set to expire on September 30, 2022. If Congress reauthorizes the SBIR/STTR programs prior to September 30, 2022, we anticipate following the schedule below for our FY 2023 Phase I Release 1 Funding Opportunity Announcement. Further information about the impact of a potential lapse in SBIR/STTR authorization will be included in the Funding Opportunity Announcement.

Event	Dates
Topics Released:	Monday, July 11, 2022
Funding Opportunity Announcement Issued:	Monday, August 8, 2022
Letter of Intent Due Date:	Monday, August 29, 2022 5pm ET
Application Due Date:	Tuesday, October 11, 2022 11:59pm ET
Award Notification Date:	Tuesday, January 3, 2023*
Start of Grant Budget Period:	Monday, February 13, 2023*

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	July 11, 2022	Original
Ver. 2	July 15, 2022	• Introduction to SBIR/STTR DOE Topics: Updated link to DOE Learning site
Ver. 3	August 3, 2022	• Topic 4, subtopic b: Updated description

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INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2023 DOE SBIR/STTR Phase I Release 1 Funding Opportunity Announcement scheduled to be issued on August 8, 2022. 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.osti.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: https://science.osti.gov/SBIRLearning. 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 technical and business assistance (TABA) either through a DOE-funded and selected contractor or through an awardee-funded and selected vendor(s).

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 TTO?
A 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 Laboratory Contractor 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 Contractor 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 Laboratory Contractor and your project plan should reflect this.

How do I draft a subaward?
The technology transfer office of the collaborating university or DOE Laboratory will typically be able to assist with a suitable template.

Am I required to show I have a subaward with the university or National Laboratory Contractor 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 Laboratory Contractor via a subaward may help to accelerate the research or development effort. In those cases, the small business may wish to negotiate a subaward with the university or National Laboratory.

Is the university or National Laboratory Contractor required to become a subawardee if requested by the applicant?
No. Collaborations with universities or National Laboratory Contractors must be negotiated between the applicant small business and the research organization. The ability of a university or National Laboratory Contractor 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 an exclusive or non-exclusive license to the technology is available for negotiation. 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 granted 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 a no-cost, six month option to license the technology at the start of the Phase I award. 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 Laboratory Contractor 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?

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By leveraging prior research and patents from a university or National Laboratory Contractor 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.

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PROGRAM AREA OVERVIEW: OFFICE OF ADVANCED SCIENTIFIC COMPUTING RESEARCH

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

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

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

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

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

Please note that all DOE SBIR/STTR grant projects requiring high performance computing support are eligible to apply to use DOE NERSC resources. See more info and how to apply: https://science.osti.gov/sbir/Applicant-Resources/National-Labs-Profiles-and-Contacts/National-Energy-Research-Scientific-Computing-Center

In addition, applicants may consider to apply for Director's Discretionary allocation at the DOE's Open Science Computing facilities: the Oak Ridge Leadership Computing Facility (OLCF) [1], the Argonne Leadership Computing Facility (ALCF) [2], or the National Energy Research Scientific Computing Center (NERSC) [3]. Applicants who already have used the DOE facilities, may consider applying for the ALCC program [4]. ALCF has a site that includes everything an applicant may need to know to apply for allocation and get training: http://www.alcf.anl.gov/user-guides/how-get-allocation. Questions concerning allocations on the ALCF can be sent to David Martin, dem@alcf.anl.gov.

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Descriptions of the allocation programs available at the OLCF are available at http://www.olcf.ornl.gov/support/getting-started/. Questions concerning allocations on the OLCF can be sent to Bronson Messer, bronson@ornl.gov.

Proprietary work may be done at the ALCF and OLCF facilities using a cost recovery model.

References:

1. Oak Ridge Leadership Computing Facility, U.S Department of Energy, 2021, OLCF Director's Discretion Project Application, *Oak Ridge National Laboratory Leadership Computing Facility,* https://www.olcf.ornl.gov/for-users/documents-forms/olcf-directors-discretion-project-application/, (June 23,2021) Contact: Bronson Messer, bronson@ornl.gov
2. Argonne Leadership Computing Facility, U.S Department of Energy, 2021, Director's Discretionary Allocation Program, *Argonne Leadership Computing Facility,* https://www.alcf.anl.gov/science/directors-discretionary-allocation-program, (June 23, 2021) Contact: Katherine Riley, riley@alcf.anl.gov
3. NERSC, U.S. Department of Energy, Lawrence Berkeley National Laboratory, 2021, Apply For Your First NERSC Allocation, NERSC, https://www.nersc.gov/users/accounts/allocations/first-allocation/, (June 23, 2021) Contact: Richard Gerber, ragerber@lbl.gov
4. DOE ALCC Program, U.S Department of Energy, 2021, ASCR Leadership Computing Challenge (ALCC), U.S. Department of Energy Office of Science, https://science.osti.gov/ascr/Facilities/Accessing-ASCR-Facilities/ALCC, (June 23, 2021)

C55-01 ACCELERATING THE DEPLOYMENT OF ADVANCED SOFTWARE TECHNOLOGIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Office of Science (SC) Office of Advanced Scientific Computing Research (ASCR) has spent decades on, and invested millions of dollars in, the development of HPC software that operates efficiently on large, heterogeneous supercomputers. Today, this hardware (e.g., CPUs, GPUs, TPUs, ASICs) has permeated society at large, finding its way into everything from smart phones to cloud computers. However, many of the software packages and libraries that can take advantage of this heterogeneity have remained solely within the HPC ecosystem.

Work proposed under this topic must critically depend on one or more ASCR-funded software packages. Applications should include a reference (webpage or other citation) to show that the relevant software has been supported by ASCR. Relevant ASCR-funded software packages include, but are not limited to:

- Mathematical Libraries: SuperLU (https://portal.nersc.gov/project/sparse/superlu/), STRUMPACK (https://portal.nersc.gov/project/sparse/strumpack/), HYPRE (https://www.llnl.gov/casc/hypre/), Trilinos (https://trilinos.github.io/), PETSc (https://www.mcs.anl.gov/petsc/), SUNDIALS (https://computing.llnl.gov/projects/sundials), MFEM (https://mfem.org/).
- Programming Models: Kokkos (https://github.com/kokkos/kokkos), RAJA (https://github.com/LLNL/RAJA), Umpire (https://github.com/LLNL/umpire), Legion (https://legion.stanford.edu/)
- I/O: ADIOS2 (https://github.com/ornladios/ADIOS2), Parallel NetCDF (https://parallel-netcdf.github.io/), HDF5 (https://www.hdfgroup.org/)
- Compilers and Runtimes: LLVM (https://llvm.org/), Argobots (https://www.argobots.org/)
- MPI: OpenMPI (https://www.open-mpi.org/), MPICH (https://www.mpich.org/)
- Package Management: Spack (https://spack.io/)

- Software Stacks and SDKs: E4S (https://e4s-project.github.io/), xSDK (https://xsdk.info/).
    - Please note that E4S and xSDK include many ASCR-funded software packages that are not separately listed in this document.

See the references for an additional, partial listing of available software packages and examples of their uses. Applications without a critical dependence on one or more ASCR-funded software packages are out of scope.

ASCR understands that a diverse community of stakeholders contributing to the maintenance and evolution of a software package lowers the long-term risks associated with commercialization of that software. Accordingly, ASCR encourages contributing fixes for defects in the ASCR-funded software, changes needed to make the ASCR-funded software function on generally-available platforms, and other *non-proprietary* enhancements of general utility to the ASCR-funded software back to the project in a manner consistent with any applicable licensing requirements and other project policies. While not required, applicants are encouraged to provide letters of support from at least one developer of each ASCR-funded software package that plays a significant role in the proposed work. This letter should outline the mutually-understood procedure via which any relevant contributions will be reviewed for acceptance into the project and *briefly outline* any anticipated prerequisites to initiating that procedure (e.g., the future execution of a Contributor License Agreement (CLA)).

ASCR will consider collaborative applications from teams of small businesses under this topic, with up to three small businesses forming a team. Each institution in such a team must be a small business. Each institution may include one or more academic or lab partners as subcontractors. Each institution must submit an application that contains an identical narrative section and a common statement describing how any Intellectual Property (IP) issues will be addressed by the collaboration. Each application must have an institution-specific budget and budget-justification forms, biographical data for the PI and senior personnel involved in the project, and a commercialization plan. The budget proposed for each participating business must separately comply with the ceiling, floor, and other requirements in the Funding Opportunity Announcement. The cover sheet for each submission must clearly show all institutions involved in the collaboration.

a. Deployment of ASCR-Funded Software

Accelerating the deployment and use of advanced, ASCR-funded software technologies, packages, and libraries can significantly improve the performance, reliability, and stability of commercial applications while lowering the cost of developing new capabilities. While many ASCR-supported software packages are open source, they are often complicated to use, distributed primarily in source-code form targeting common HPC systems, and potential adopters lack options for purchasing commercial support, training, and custom-development services. The expertise required to install and use these software packages poses a significant barrier to many organizations due to the levels of complexity built into them to facilitate scientific discovery and research. Moreover, without a commercial interest in broadly marketing the capabilities of the software, possibly including in markets beyond HPC, adoption is limited by a lack of exposure within the wider technology ecosystem. Providing simpler interfaces targeted for specific markets, or offering a spectrum of commercial services around the underlying open-source software, would make these software packages more usable for commercial, industrial, and non-scientific applications.

Grant applications are sought to take one or more ASCR-funded software packages and make them easier to use by a wide variety of industries or in commercial venues by developing commercial offerings based on those ASCR-funded software packages. This may include design, implementation, and usability testing of Graphical User Interfaces (GUIs), web interfaces, or interfaces for alternative programming languages (e.g., using Python, R, or Julia); porting to other platforms (e.g., cloud, mobile); simplification of user input;

decreasing complexity of the code by stripping out components not required; hardening the code to make it more robust; adding new capabilities; adding user-support tools or services; or other ways that make the code more widely useable to industrial applications.

Questions – Contact: Hal Finkel, Hal.Finkel@science.doe.gov and/or William Spotz, William.Spotz@science.doe.gov

b. Integration of ASCR-Funded Libraries

Adopting and integrating advanced, ASCR-funded libraries into commercial products can lower the cost of developing new capabilities while simultaneously providing improved performance, reliability, and stability. The advanced mathematical and computational algorithms, and support for state-of-the-art hardware, can be leveraged by commercial software *internally*, thereby providing important capabilities without users interacting directly with the capabilities provided by the underlying ASCR-funded libraries. These commercial applications need not be targeted at HPC systems, but rather, may integrate and adapt the relevant ASCR-funded libraries for use in cloud, mobile, or other computing environments.

Grant applications are sought to take one or more ASCR-funded libraries and integrate them into new or existing, commercially-supported software products to provide unique, transformative capabilities. Applicants may choose to strip out code components, harden them, or perform any other tasks necessary to meet deployment requirements in the context of the envisioned commercial product.

Questions – Contact: Hal Finkel, Hal.Finkel@science.doe.gov and/or William Spotz, William.Spotz@science.doe.gov

c. Other

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

Questions – Contact: Hal Finkel, Hal.Finkel@science.doe.gov and/or William Spotz, William.Spotz@science.doe.gov

References:

1. U.S. Department of Energy, 2022, Software, Scientific Discovery through Advanced Computing (SciDAC), U.S. Department of Energy, https://www.scidac.gov/software-list.html (June 23, 2022)
2. U.S. Department of Energy, 2022, SciDAC Feature, Scientific Discovery through Advanced Computing (SciDAC), U.S. Department of Energy, http://www.scidac.gov (June 23, 2022)
3. Heroux, M. A., Carter, J., Thakur, R., Vetter, J. S., McInnes, L. C., Ahrens, J., Munson, T., and Neely, J. R., 2020, ECP Software Technology Capability Assessment Report-Public, ECP-RPT-ST-0002-2020-Public, https://www.exascaleproject.org/wp-content/uploads/2020/02/ECP-ST-CAR-V20-1.pdf (June 23, 2022)
4. U.S. Department of Energy, 2022, Exascale Computing Project, https://www.exascaleproject.org/ (June 23, 2022)
5. U.S. Department of Energy, 2022, DOE CODE, U.S. Department of Energy, Office of Scientific and Technical Information, https://www.osti.gov/doecode/ (June 23, 2022)
6. Market Research Study: Applications of ASCR HPC Software, 2022, https://science.osti.gov/ascr/Community-Resources/Program-Documents (June 27, 2022)

C55-02 HPC CYBERSECURITY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000

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Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Large scale computationally intensive platforms, systems, facilities relying on High Performance Computing (HPC) systems to enable large scale information processing for a multitude of areas such as business, utility, financial, scientific, and national infrastructure systems that form the backbone of our nation's economy, security, and health. HPC facilities, centers, infrastructure, or resources are designed to be easily accessible by users over a worldwide network, and ensuring effective cybersecurity monitoring, situational awareness, logging, reporting, preventions, remediation, etc, is an increasingly important task. An application submitted to this topic area must be unclassified and clearly address solutions for state-of-the-art HPC systems.

Applications or proposals that do not address the range of desired products mentioned in this specific topic or are primarily focused on: Single node/host-, handheld-, mobile-, cloud-, cryptography-, statistical-, grid-, desktop-, and/or wireless-based solutions; internet; networking; internet-of-things; internet-of-everything; ransomware; blockchain; enterprise; deception; virtualization; out-of-band; cyber-physical; data centers; database; basic research; natural language processing; collaborative computing; computing clusters; distributed computing; human factors; computer human interactions; not focused specifically on state-of-the-art HPC systems; visualization; social media; data analytics; web applications; social networks; authentication; firewall; hardware; edge computing; cryptanalysis; encryption; or propose to change, modify, and/or alter application's code, will be considered nonresponsive and will not undergo merit review.

Grant applications are sought in the following subtopics:

a. Cybersecurity Technologies

This topic solicits unclassified applications that will deliver and market commercial products ensuring effective and practical cybersecurity for HPC systems, centers, and/or user facilities. The application must clearly address solutions for state-of-the-art HPC systems in particular. These tools will have the capability to detect, prevent, or analyze attempts to compromise or degrade systems or applications consequently increasing their cybersecurity. Any submitted application must be unclassified.

Relevant evaluation metrics may include delivery of potential solutions involving minimizing the overall security overhead required to deal with data parallelism, concurrency, storage and retrieval, hardware heterogeneity, and how to monitor, visualize, categorize, or report cybersecurity challenges effectively. Current cybersecurity tools and products could potentially be enhanced or transitioned to help secure HPC systems. However, any proposal idea must specifically and clearly address solutions geared for state-of-the-art HPC systems.

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

b. Other

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

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

References:

1. DOE Workshop Report, 2015, ASCR Cybersecurity for Scientific Computing Integrity - Research Pathways and Ideas Workshop, DOE Workshop Report, https://escholarship.org/uc/item/89s6w301 (June 24, 2022)
2. U.S. Department of Energy, Office of Science, 2015, ASCR Cybersecurity for Scientific Computing Integrity, DOE Workshop Report, (January 7-9, 2015), https://science.osti.gov/-/media/ascr/pdf/programdocuments/docs/ASCR_Cybersecurity_For_Scientific_Computing_Integrity_Report_2015.pdf (June 27, 2022)
3. Campbell, S., and Mellander, J., 2011, Experiences with Intrusion Detection in High Performance Computing, https://cug.org/5-publications/proceedings_attendee_lists/CUG11CD/pages/1-program/final_program/Monday/03B-Mellander-Paper.pdf (June 24, 2022)
4. Malin, A.B., and Van Heule, G.K., 2013, Continuous Monitoring and Cyber Security for High Performance Computing, Report LA-UR-13-21921, http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-13-21921 (June 24, 2022)

C55-03 DIGITAL TWIN CAPABILITIES FOR SCIENCE NETWORK INFRASTRUCTURES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Digital Twins are an emerging area of modern science where a physical object (i.e., device, process, or infrastructure) is mated with a digital (virtual) version of that same object. Operation of the physical object can generate data to validate the virtual objects behavior while the virtual object allows rapid exploration of input parameters that might damage the physical object. It is this close interaction between the physical and virtual object that makes this Digital Twin environment so productive.

DOE has a long history of building and operating high performance physical network infrastructures. The Energy Science Network (ESnet) supports the Office of Science lab complex and it also peers with other Research and Education networks (RENs) both domestically and internationally. ESnet also operates an internal 100G SDN network testbed and the NSF funded FABRIC external network testbed. Specifically:

- ESnet 100G SDN: The objective is to provide network researchers with a realistic environment for testing. Current testbed enables 100G application / middleware experiments, Science DMZ and SDN control/data plane experiments.

- FABRIC: The National Science Foundation (NSF) collaboration is building a national research infrastructure that will enable the computer science and networking community to develop and test novel architectures that could yield a faster, more secure Internet.

What is missing is the virtual (Digital Twin) companion to these testbeds.

This topic solicits applications that would create the network simulation capabilities that would accurately and reliably duplicate the operational and performance capabilities of these testbeds creating their Digital Twin.

a. Network Simulation Tools

Over the past few decades, the network research community has developed multiple network simulators (i.e., NS-3, OMNeT++, OPnet, ROSS) and emulators (i.e., Mininet) tools. While these tools have demonstrated value, there are limitations on the speed and capability that must be addressed for them to become an effective Digital Twin of one of these testbeds. In addition, there are new functionalities and devices (i.e.; P4 switches, Optical Add/Drop Muxes, security) that are integral components of these testbeds that need to be incorporated.

To be an effective Digital Twin, the simulator/emulator must be as fast as, or faster than, the physical network. They should also be capable of evaluating new network link technologies or speeds (up to 1 Tbps links) that are expected in the next few years. Both of these testbeds span national (U.S.) and international (EU) boundaries. This means Round Trip Times range from a few msec to over 100 msec. It also means that the event rate can vary from 8.3M pkts/sec (1500 Byte Ethernet frames) to 1.9B pkts/sec (64 Byte Ethernet frames). These event rates will place a heavy burden on simple Discrete Event Simulators (DESs). Work on Parallel DES's, Artificial Intelligence / Machine Learning (AI/ML) based surrogate models, and/or hybrid tools that automatically combine both methods are the focus of this subtopic.

Specifications:
The simulation/emulation tool(s) must meet the following criteria:

- Link Speed: equal to or 10x faster than the physical testbed
- Topology: exactly matches the physical testbed
- Node support: exactly match the operational capabilities of the installed routers, switches, and hosts.
- Protocol support: support the physical (optical), network (IPv4 and IPv6), transport (all current variants), and commonly used science applications.
- Event Rate: a minimum of 2 Billion events/sec (discrete or surrogate model)

Applications are solicited to enhance or extend one or more existing simulation/emulation tools to create a Digital Twin of either the ESnet 100 G SDN testbed or the FABRIC testbed.

Out of scope:

- Creation of a new simulation/emulation tool from scratch.
- Creation of a Digital Twin of other testbeds or infrastructures.
- Enhancements or extensions that only meet a subset of the specifications.

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

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

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

References:

1. ESnet Energy Science Network, 2022, 100G SDN Testbed, ESnet Energy Sciences Network, https://www.es.net/network-r-and-d/experimental-network-testbeds/100g-sdn-testbed/ (June 24, 2022)
2. Esnet Energy Sciences Network, 2022, Fabric, Esnet Energy Sciences Network, https://www.es.net/network-r-and-d/fabric/ (June 24, 2022)
3. FABRIC Knowledge Base, 2022, FABRIC Knowledge Base, https://learn.fabric-testbed.net/ (June 27, 2022)
4. Wikipedia, 2022, Digital Twin, Wikipedia, https://en.wikipedia.org/wiki/Digital_twin (June 24, 2022)

References: Subtopic a:

1. NSnam, 2022, NS-3 Network Simulator, https://www.nsnam.org/ (June 24, 2022)
2. OMNeTpp, 2022, OMNeT++ Discrete Event Simulator, https://omnetpp.org/ (June 24, 2022)
3. Mininet, Mininet An Instant Virtual Network On Your Laptop (or other PC), http://mininet.org/ (June 24, 2022)
4. OPnet, 2022, OPnet Network Simulator, https://opnetprojects.com/opnet-network-simulator/ (June 24, 2022)
5. ROSS, 2022, ROSS, https://ross-org.github.io/about.html (June 24, 2022)
6. Carothers, C.D., Bauer, D., and Pearce, S., 2002, ROSS: A high-performance, low-memory, modular Time Warp system, Journal of Parallel and Distributed Computing, (Volume 62, Issue 11, 1648–1669), https://www.sciencedirect.com/science/article/abs/pii/S0743731502000047 (June 24, 2022)
7. Wikipedia, 2022, Surrogate models, https://en.wikipedia.org/wiki/Surrogate_model (June 24, 2022)
8. Wolfe, N., Misbah M., Carothers, C.D., Ross, R.B., and Carns, P.H., 2018, Modeling Large-Scale Slim Fly Networks Using Parallel Discrete-Event Simulation, ACM Transactions on Modeling and Computer Simulation (TOMACS), (28, no. 4 (2018): 1-25), https://www.researchgate.net/publication/327430844_Modeling_Large-Scale_Slim_Fly_Networks_Using_Parallel_Discrete-Event_Simulation (June 24, 2022)

C55-04 TECHNOLOGY TO FACILITATE THE USE OF NEAR-TERM QUANTUM COMPUTING HARDWARE

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

This topic is focused on specific technologies that are required to advance the state of quantum computing and networking. One focus is to facilitate effective implementation of gate-based quantum computing methods on quantum processors available or expected to be available within the next five years. The other focus is on the development and demonstration of a technique for ultra-low-loss integration of two or more quantum network components (for example, but not limited to, an entangled photon source and photon detector) to achieve a higher-level network function.

Grant applications are sought in the following subtopics:

a. Software for Calibration, Characterization, and Control of Quantum Processors
Effective use of near-term quantum processors requires device-specific optimization of individual operations ranging from state preparation and measurement through gate implementation and compilation. Specialized techniques and tailored pulse sequences can suppress noise, mitigate crosstalk and control errors, and maintain optimally high-fidelity operations in the absence of formal error correction. In many cases, regular calibration and device characterization are necessary to ensure optimal performance. As algorithmic complexity and the size of qubit arrays grow, control software also increases in complexity. It is increasingly important to develop control software that combines knowledge of specific characteristics of a device, quantum algorithms, and high-efficiency optimization techniques. Grant applications are sought to develop and validate software tools for automated processor tune-up, characterization, calibration, and optimization of quantum processors; implementation of techniques for suppressing decoherence and mitigating errors; and automation of benchmarking and compiling protocols. Open source software solutions are strongly encouraged, as is testing the software solutions on fully transparent quantum computing platforms available in research laboratories.

Grant applications focused on quantum annealing, analog simulation, or other non-gate-based approaches to quantum computing will be considered out of scope.

Questions – Contact: Claire Cramer, Claire.Cramer@science.doe.gov

b. Ultra-Low-Loss Integration of Heterogeneous Quantum Internet Devices

As quantum network devices continue to advance in capability, quantum networks are growing in scale – increasing in range, number of users and architectural complexity. Eventually many local and regional quantum networks will merge to form the quantum internet.

Operational losses of individual quantum network devices will compound as devices connect and the network grows larger. Today, foundational building blocks of the quantum internet are being developed using diverse technical approaches, many of which have benefits and merit exploration. These devices include, but are not limited to, quantum memories, entangled photon and single photon sources and detectors, quantum multiplexors, switches, frequency converters and transducers. Mechanisms of loss that arise from integration of heterogeneous quantum network devices become increasingly important to understand and mitigate as quantum networks scale.

Today, quantum network devices are in early stages of development. Co-design of early-stage quantum network devices with ultra-low-loss, high-efficiency integration techniques will become increasingly essential as quantum networks scale. This topic requests development and demonstration of ultra-low-loss, high-efficiency integration techniques that interface two or more quantum network devices with each other to create a hybrid device that provides a larger quantum network function. It is required that at least two or more quantum network devices be integrated.

Both insertion loss between devices and data loss within a particular device contribute to the combined losses that the integrated quantum network device must be able to tolerate. This topic area is focused on reduction of insertion loss. In the narrative, please estimate the insertion loss in db that you expect your proposed integration technique to achieve. Also, please discuss the assumptions made to arrive at this estimated value of insertion loss and support the assertion that the expected insertion loss is low enough for the integrated quantum network device to function.

Examples of integration include, but are not limited to, ultra-low-loss on-chip integration of two or more quantum network devices, or ultra-low-loss interconnection of two or more quantum network devices using optical fiber where ultra-low-loss fiber-coupling of at least one of the devices has not been previously demonstrated.

The applicant is required to specify the quantum network devices that will be the focus of their integration efforts, and clearly describe the larger quantum network function that integration of these devices will achieve. Example component devices to be interfaced could be, but are not limited to, single or entangled photon sources and detectors. The proposed effort should include a systems-level engineering approach that harmonizes relevant operational properties of component devices to enable their ultra-low-loss, high-efficiency integration.

Questions – Contact: Carol Hawk, Carol.Hawk@science.doe.gov

References: Subtopic a:

1. U.S. Department of Energy, 2017, ASCR Report on a Quantum Computing Testbed for Science, Office of Advanced Scientific Computing Research, (p. 46),

https://science.osti.gov/~/media/ascr/pdf/programdocuments/docs/2017/QTSWReport.pdf (June 24, 2022)

References: Subtopic b:

1. U.S. Department of Energy, 2020, From Long-distance Entanglement to Building a Nationwide Quantum Internet: Report of the DOE Quantum Internet Blueprint Workshop, https://www.osti.gov/biblio/1638794-from-long-distance-entanglement-building-nationwide-quantum-internet-report-doe-quantum-internet-blueprint-workshop (June 24, 2022)

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PROGRAM AREA OVERVIEW: OFFICE OF BASIC ENERGY SCIENCES

The Office of Basic Energy Sciences (BES) supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support Department of Energy (DOE) missions in energy, environment, and national security. The results of BES-supported research are routinely published in the open literature.

A key function of the program is to plan, construct, and operate premier scientific user facilities for the development of novel nanomaterials and for materials and chemical characterization through x-ray and neutron scattering; the former is accomplished through five Nanoscale Science Research Centers and the latter is accomplished through the world's largest suite of light source and neutron scattering facilities. These national resources are available free of charge to all researchers based on the quality and importance of proposed nonproprietary experiments. For additional information on BES user facilities, click here. The link to each facility webpage leads to detailed descriptions of the experimental facilities and the listing of available experimental techniques.

A major objective of the BES program is to promote the transfer of the results of our basic research to advance and create technologies important to Department of Energy (DOE) missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, the mitigation of the adverse impacts of energy production and use, and future nuclear energy sources. Here is a tool from DOE Office of Technology Transitions to discover and partner with DOE's National Labs. The DOE SBIR/STTR site also contains a resource to explore collaboration with the National Labs.

The following set of technical topics represents one important mechanism by which the BES program augments its system of university and laboratory research programs and integrates basic science, applied research, and development activities within the DOE. For additional information regarding the Office of Basic Energy Sciences priorities, click here.

C55-05 DEVELOPMENT OF TOOLS FOR INTEGRATING AND UTILIZING COMPLEX DATA FROM CHEMICAL SCIENCES, GEOSCIENCES, AND BIOSCIENCES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Fundamental science efforts in the Chemical Sciences, Geosciences, and Biosciences (CSGB) Division (reference 1) produce significant amounts of system-specific data for relevant energy systems. Recent reports (reference 2) pinpoint topical opportunities in which multimodal approaches are needed to increase impact of fundamental research on applied technology. In particular, artificial intelligence/machine learning (AI/ML) tools are needed to facilitate the integration of highly heterogeneous data, promote data sharing for model fine-tuning and generalization, extrapolate to data-poor regions, or extend fundamental theories to complex, many-parameter systems.

Grant applications are sought in the following subtopics:

a. AI/ML Framework for Multi-Modal Analysis of Complex Data

Experimental measurements and computational simulations of physicochemical phenomena produce complex data that are disparate, non-uniform, or unstructured. This presents multiple challenges to data analysis efforts. It can be difficult to extend analytical models based on these data beyond the specific system(s) studied. Moreover, data derived from diverse techniques and research communities can be challenging to integrate. However, when combined, these data may provide an opportunity to generate comprehensive models by combining orthogonal data (e.g., multiple types of spectroscopic and structural characterization data, and reactivity and transport data). Relevant complex data impacted by these challenges are found in many areas of chemical sciences, geosciences and biosciences research including (but not limited to) the following, with references to example databases:

- Reaction kinetics, compositional, and spectroscopic information on chemical conversions (see reference 3 and 4 for examples)
- Structural information of active sites and motifs (see reference 5 and 6 for examples)
- Synthesis protocols (see reference 6 for examples)
- Geochemical and geophysical data to understand subsurface chemistry
- Biochemical and biophysical data to understand energy storage and conversion in organisms

Since valuable and relevant data are not always present in extant databases, principal investigators are encouraged to consider and identify multiple sources of information such as datasets found in reference 7, experimental and computational publications from diverse research groups, etc. Tools are needed to facilitate the compilation, homogenization, and validation of these data and their distribution among physicochemical modelers working in the chemical sciences, geosciences and biosciences. Advanced tools are also needed to enhance physical models by using AI/ML algorithms, and to facilitate transferability of physical and data models outside their narrow training domains. Applicants should refer to the relevant reports mentioned in reference 2 to identify priority research directions/opportunities in one or more of the areas mentioned above.

Applications that propose software solutions alone without addressing one or more of those priority research opportunities or directions would be out of scope for this solicitation. Approaches that do not use the most current AI/ML methods will be considered unresponsive to this topic.

Questions – Contact: Aaron Holder, Aaron.Holder@science.doe.gov and Raul Miranda, Raul.Miranda@science.doe.gov

b. Other

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

Questions – Contact: Aaron Holder, Aaron.Holder@science.doe.gov and Raul Miranda, Raul.Miranda@science.doe.gov

References:

1. U.S. Department of Energy, 2022, Chemical Sciences, Geosciences, & Biosciences (CSGB) Division, U.S. DOE Office of Science, https://science.osti.gov/bes/csgb (June 17, 2022)
2. U.S. Department of Energy, 2022, Community Resource Reports, U.S. DOE Office of Science, https://science.osti.gov/bes/Community-Resources/Reports, (June 17, 2022)
3. Catalysis Hub Center for Interface Science and Catalysis (SUNCAT), 2019, https://www.catalysis-hub.org/ (June 17, 2022)
4. National Institute of Advanced Industrial Science and Technology (AIST), 2022, Spectral Database for Organic Compounds SDBS, https://sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi (June 17, 2022)

5. Regents of the University of Minnesota, 2022, Nanoporous Materials Genome Center, http://www1.chem.umn.edu/nmgc/software/ (June 17, 2022)
6. J. Mistry, Chuguransky S., Williams L., Qureshi M., Salazar G., Sonnhammer E., Tosatto S., Paladin L., Raj S., Richardson L., Finn R., Bateman A., 2021,Nucleic Acids Research (2020) doi: 10.1093/nar/gkaa913, https://pfam.xfam.org/ (June 17, 2022)
7. U.S. Department of Energy, 2022, DOE Data Explorer, Office of Science and Technical Information, U.S. DOE Office of Science, https://www.osti.gov/dataexplorer/ (June 17, 2022)

C55-06 CRYOSTAT FOR TESTING SUPERCONDUCTING UNDULATOR MAGNETS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Superconducting undulator (SCU) technology has held tremendous promise for radiation sources in storage rings and free electron lasers for several decades. Many of the technical challenges associated with the design, fabrication, and operation of SCUs have been resolved, with SCUs regularly operating in two light sources worldwide and with plans for several more under consideration. SCUs offer several advantages over permanent magnet undulators as radiation sources including: 1) enhanced magnetic field, yielding shorter undulator periods and broader photon energy tuning range compared with most advanced permanent magnet undulators, especially for hard x-ray photon energies above ~20 keV; 2) flexible magnetic field configurations enabled by flexible winding configurations of the superconducting wire; 3) a compact transverse profile that could enable multiple SCUs in a single cryostat; and 4) longer lifetime due to reduced sensitivity to radiation damage.

Grant applications are sought in the following subtopics:

a. Development of Cryostat for Testing Superconducting Undulator Magnets
This topic seeks the development of a diagnostic cryostat for fast testing of superconducting undulator (SCU) magnets. Superconducting undulator is an emerging accelerator technology offering a high undulator field that can be realized in a variety of configurations including planar, helical, and universal undulator. Various superconductor materials can be used for winding SCU magnet coils, leading to multiple options for SCU magnet design that should be experimentally verified. Diagnostic cryostats are needed for the experimental verification. Undulator magnets are provided by the customer and will be tested using the cryostat described in this topic. The primary components of the cryostat should include:

i. Vacuum chamber of length approximately 3 m and transverse dimensions of the order of 1 m to accommodate undulator magnets up to 2 m long and cross-sections up to 0.3 m x 0.3 m in the horizontal orientation. Cryogenic cooling and magnet support systems are also required.
ii. Cryogenic cooling system capable of providing at least 4 watts of refrigeration at an operating temperature of 4.2 K. The system should have an operating temperature range between 3 K and 5 K and include appropriate thermal insulation consistent with cryogenic engineering practice.
iii. Thermal links or other heat transport mechanism capable of transporting heat from the test magnet to the cooling system. An efficient thermal transport system should minimize the temperature difference between the cryogenic cooling system and the test magnet down to about 0.1 K.
iv. Support system to suspend, align, and thermally isolate the test magnet from the cryostat.
v. Two pairs of current leads capable of supporting up to 2 kA and six pairs of current leads capable of supporting up to 250 A. Leads should include a high-temperature superconductor component to avoid the need for vapor cooling.

vi. Instrumentation sufficient to monitor the operating condition of the cryogenic cooling system, current leads, and the undulator magnet being tested. Estimated quantity of temperature sensors required is 40.
vii. Support for a magnetic measurement system to be provided by the customer. Test undulator magnets are measured using Hall probe, wire coils, and pulsed wire techniques. In each case, the probe must traverse the cryostat in the horizontal plane, passing through the magnetic gap in the test magnet. The vacuum chamber ends must accommodate a suitable thermal, mechanical, and vacuum transition to allow the probe to enter the interior of the magnet without disturbing cryogenic operations.
viii. The cryostat should provide uninterrupted operation over test durations as long as 6 weeks.

Questions - Contact: Eliane Lessner, Eliane.Lessner@science.doe.gov

b. Other

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

Questions - Contact: Eliane Lessner, Eliane.Lessner@science.doe.gov

References:

1. Ivanyushenkov, Y., et. al., 2018, Status of the Development of Superconducting Undulators at the Advanced Photon Source, Synchrotron Radiation News (Volume 31 – Issue 3), https://doi.org/10.1080/08940886.2018.1460172 (June 21, 2022)
2. Kesgin, I., Ivanyushenkov, Y., and Gluskin, E., 2019, Practical superconducting materials for high-field Undulators, ICFA Beam Dynamics Newsletter (No. 78, pg. 61) (2019), https://www.researchgate.net/publication/340463750_ICFA_Beam_Dynamics_Newsletter (June 21, 2022)
3. Fuerst, J., et. al., 2017, A second-generation superconducting undulator cryostat for the APS, IOP Conf. Ser.: Mater. Sci. Eng. (278, 012176) (2017), https://doi.org/10.1088/1757-899X/278/1/012176 (June 21, 2022)
4. Grau, A.W., et. al., 2017, Training and Characterization of 1.5 m Long Conduction Cooled Superconducting Undulator Coils With 20 mm Period Length, Proceedings of IPAC2017, Copenhagen, Denmark, TUPAB036 (2017), https://doi.org/10.18429/JACoW-IPAC2017-TUPAB036 (June 21, 2022)

C55-07 NOVEL INSTRUMENTS AND TECHNIQUES FOR DETECTION AND REMOVAL OF CONTAMINATION PARTICULATES IN HIGH-POWER PROTON SUPERCONDUCTING LINAC RADIO FREQUENCY CAVITIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

This topic seeks the development of diagnostic instruments and surface cleaning techniques for understanding, predicting, controlling, and possibly reversing particulate contamination in superconducting radio frequency (SRF) cavities operated in high-power proton linear accelerators. Particulate contamination introduced onto the surface of an operational SRF cavity is a source of unwanted field emission. Consequently, it causes degradation of the cavity operational gradient and radiation damage to linac components. These in turn lead to a loss in the linac energy output, availability, and maintainability. Novel instruments and techniques are required to understand the source of particulates in the beamline of operational SRF linacs, the movement of pre-existing and newly generated particulates over the entire length of the beamline envelope, the stopping of particulate transportation onto the SRF cavity surfaces, and the removal of accumulated particulates from the surfaces of cavities installed in the accelerator tunnel without taking apart cryomodules. Such instruments and techniques are lacking. The applicant must propose solutions applicable for operational SRF linacs and associated cryomodule and cavity components, subjected to radiation fields and sometimes residual activation.

Grant applications are sought in the following subtopics:

a. Non-Invasive Instruments for Detecting Particulate Movement in SRF Linac Beamlines and Tools and Processes for In-Situ Removal of Particulates from SRF Cavity Surfaces of a Cryomodule Without Taking Apart Cryomodule Components

In this subtopic applications are sought for the development of non-invasive diagnostic instrument systems for detecting particulate movement in the SRF linac beamlines. The system must not interrupt the normal accelerator operation. The detection method must be compatible with the ultra-high vacuum condition within the beamline envelope. The system must be capable of resisting damage against the ionization radiation environment often found in the vicinity of the accelerator beamline. The detection technique should be sensitive to organic, inorganic, metallic, and semiconducting particulates of sizes in the range of 1-100 micron, moving at a speed in the range of 1-10 m/s. The data acquisition system should be capable and flexible in dealing effectively with different scenarios in particulate flux down to one per day. The data analysis algorithm should be able to report at minimum: the particle size and movement speed. Capabilities in discerning the type of materials of the moving particulates are highly desired.

Applications are also sought for the development of new tools and processes capable of removing particulates deposited on the surface of SRF cavities in a cryomodule without taking apart cryomodule components. The new techniques must transport the removed particulates from the inner space enclosed by the surface of a string of cavities embedded in a cryomodule. Discharged particulates must be captured to prevent release of activated particulate matter. Particulates down to 1 micron in size should be effectively dislodged and transported over a length of a multi-cell elliptical cavity (with a length on the order of 1 meter) and the entire cavity string as well (on the order of 10 meters). No scratching of the cavity iris is permitted. The design of the tool and process must be flexible to allow turning the cleaning medium on and off at demand so as to protect sensitive cryomodule components such as coupler tips and copper plating from being compromised and damaged.

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

b. Other

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

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

References:

1. Padamsee, H., Shepard, K.W., Sundelin, R., 1993, Physics and Accelerator Applications of RF Superconductivity, Annu. Rev. Nucl. Part. Sic., (Vol. 43:635-686), https://doi.org/10.1146/annurev.ns.43.120193.003223 (June 21, 2022)
2. Geng, R.L., Freyberger, A., Legg, R.A., Suleiman, R., and Fisher, A.S., 2017, Field Emission in SRF Accelerators: Instrumented Measurements for Its Understanding and Mitigation, Proc. 6th Int. Beam

Instrumentation Conf. (IBIC'17), Grand Rapids, MI, USA, Aug. 2017, (pp. 470-477). https://doi.org/10.18429/JACoW-IBIC2017-TH1AB1 (June 21, 2022)

C55-08 HIGH REPETITION RATE SAMPLE DELIVERY SYSTEM FOR SUPERCONDUCTING-RF AND MULTI-BUNCH X-RAY FREE ELECTRON LASER

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

This topic seeks the development of a high-speed sample delivery system for experiments to be performed at high-pulse-power, MHz-repetition-rate XFELs, like LCLS-II and LCLS-II-HE, and at XFELs having multi-pulse capabilities within one RF cycle with a nanosecond scale separation. When focused, high-intensity X-ray pulse trains with up to MHz or sub-GHz frequency can damage a sample in a single shot, requiring the sample material to be replaced with a new fresh sample on the time scales of a microsecond and down to a nanosecond, in time for the next shot. For some applications, like serial femtosecond crystallography, the sample may be renewed as a dilute solution in a high-speed liquid jet. However, other experiments such as a population inversion X-ray laser oscillator or regenerative amplifier, being developed to generate transform limited and fully coherent pulses, require a high sample concentration or a solid sample. Unfortunately, the velocity of the liquid jet is reduced by viscosity at higher concentration, making it difficult to reach the high speed required for high-frequency X-ray pulse repetition rates. For this class of experiments, an alternative to liquid jets capable of delivering samples at high speed, above 200 m/s, is required. A possible solution to this problem is to use a high-angular-velocity rotating disk, within which samples can be embedded, or made from the solid material to be used in the experiment. Today small electric motors are easily obtained commercially with high angular velocities in the range 50,000 to 100,000 RPM. Using a 5 cm-radius disk and an angular velocity of 60,000 RPM the tangential velocity on the disk border is 300 m/s. Such a system can be useful for many experiments to be done in the future at high-repetition rate XFELs. In addition to the speed, the system is also required to satisfy safety and durability criteria, while having the flexibility to be used for different types of experiments. Two options are to be considered: one in which the angular velocity is synchronized to the FEL pulses' repetition rate, and one in which it is not. The first case is needed for experiments such as femtosecond serial crystallography, the second for experiments using multi-pulse XFEL operation at near-GHz repetition rate.

Grant applications are sought in the following subtopics:

a. Development of High-Variable Speed Rotating Disks with Vibration Control and Long Lifetime
In this subtopic applications are sought to develop a high-angular-speed rotating disk for sample delivery to a high-repetition-rate XFEL. The required tangential speed of the target must be in the 300 m/s range while the target remains well within the Rayleigh length of the FEL pulse. The system lifetime must exceed one day of operation at full speed and must operate in a Helium atmosphere with dimensions smaller than 30x15x15 cm in order to be placed at the focal point of the X-ray pulses for the nano- to micrometer focus beamlines available at LCLS/LCLS-II. The system must be also easily interchangeable during experimental runs. The disk angular velocity must be controllable, and in the case of use at MHz frequencies with a superconducting FEL, it must be possible to synchronize the angular velocity with the linac frequency. A full system demonstration is expected to be performed by the end of the contract.

Questions - Contact: Eliane Lessner, Eliane.Lessner@science.doe.gov

b. Other

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

Questions - Contact: Eliane Lessner, Eliane.Lessner@science.doe.gov

References:

1. U.S. Department of Energy, 2014, LCLS-II Conceptual Design Report, SLAC National Accelerator Laboratory Library, LCLS-II Conceptual Design Report, SLAC-R-1092 (2014), http://slac.stanford.edu/pubs/slacreports/reports09/slac-r-1092.pdf (June 21, 2022)
2. Aquila, A., et al., 2015, The linac coherent light source single particle imaging road map, Structural Dynamics 2, (041701), (2015), https://doi.org/10.1063/1.4918726 (June 21, 2022)
3. Halavanau, A., Benediktovitch, A., Rohringer, N., Wu, J., and Pellegrini, C., 2019, Preliminary considerations of atomic inner-shell X-ray laser for self-seeding at LCLS-II, Proc. of the Intern. Particle Accelerator Conf., Melbourne, Australia (2019), https://doi.org/10.18429/JACoW-IPAC2019-TUPRB090 (June 22, 2022)
4. Halavanau, A., Benediktovitch, A., Lutman, A., DePonte, D., Cocco, D., Rohringer, N., Bergmann, U., and Pellegrini, C., 2020, Population Inversion X-ray Laser Oscillator, Proc. National Academy of Sciences, (117(27),15511-15516), https://doi.org/10.1073/pnas.2005360117 (June 22, 2022)
5. Decker, F.J., et al., 2022, Tunable x-ray free electron laser multi-pulses with nanosecond separation, Scientific Reports, (12, Article: 3253), https://doi.org/10.1038/s41598-022-06754-y (June 22, 2022)

C55-09 TIME RESOLVED ULTRAFAST CIRCULAR DICHROISM SPECTROSCOPY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Optical chirality has become a central subject in the investigation of the electronic structure of both organic and inorganic quantum materials. While chiral features have been traditionally associated with molecules, topological crystalline materials have been found to exhibit chiral quantum states that can be probed and controlled by circular polarized light. Example of chiral phenomena are chiral-induced spin selectivity from chiral molecules and chiral edge states in 2D quantum spin Hall systems, where opposite spin states counterpropagate at the edge of the material. Probing chirality-resolved carrier dynamics in real time is key to understand biomolecular interactions and to control emergent topological states. Applications range from quantum information science (QIS) and novel microelectronics to drug design and development [1-4]. Because chiral light–matter interactions are inherently weak, chiral sensitivity has not been readily available in time-resolved absorption spectroscopy. The task of this call is to develop pump-broadband probe transient circular dichroism spectroscopy to measure the ultrafast temporal evolutions of charge carriers in chiral systems. This technique will advance nanoscale manipulation of quantum spins with promising applications to spintronics, valleytronics, and quantum computing.

Grant applications are sought in the following subtopics:

a. Development of Ultrafast, Transient Circular Dichroism Spectroscopy for Chiral Optical Materials

In this subtopic, we seek applications for the development of shot-by-shot transient circular dichroism spectroscopy (TCDS) where the TCDS method can be implemented as a stand-alone technique, or as an add-on option to a commercial pump-probe ultrafast spectrometer (Ultrafast Systems, CLARK-MXR Inc, Light Conversion and others). TCDS shall be capable of measuring spectrally-resolved temporal evolution of chirality in organic and inorganic compounds, including molecules, nanoparticles and 2D materials, across a broad spectrum, from UV, to VIS, to NIR (350-1600 nm) and over decades of time, from femtoseconds to microseconds.

In this application, we seek the development of TCDS where transient circular dichroic (CD) signals are measured following a shot-by-shot approach [5]. This is different from the approach reported in [3,4] involving a time average of left- and right-polarized components, separately. By utilizing ultrafast Pockell cells in sync with a kHz-repetition-rate, ultrafast laser, a transient CD spectrum can be acquired from two consecutive laser pulses (shots), each producing the left- and the right-polarized transient spectra signals used to compose the transient CD spectrum. Pockell cells or pulse pickers provide fast changes of optical polarization of the pump-and-probe signals derived from the same laser pulse shot by an ultrafast laser amplifier. The resulting shot-by-shot transient CD spectrum is free of average integrated optical and electronic noise. Furthermore, an overall transient CD spectrum can be calculated from integrating shot-by-shot CD spectra recorded across many laser shots, as many as needed, depending on the chirality strength and sample resistance to laser damage. Further increase in signal-to-noise in the CD measurement can be achieved by implementing a probe/reference balanced detection approach which can account for laser fluctuations over the course of the experiment. This TCDS approach can ultimately provide an ability to measure short-lived transient species with high chiral activity. This TCDS approach is expected to dramatically increase S/N ratio of TCDS, which is a limiting factor in conventional (averaged) measurements. Successful development of this technique will provide added capability to commercially available ultrafast optical spectroscopy solutions.

Questions - Contact: Claudia Cantoni, claudia.cantoni@science.doe.gov

b. Other

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

Questions - Contact: Claudia Cantoni, claudia.cantoni@science.doe.gov

References:

1. Hache, F., 2009, Application of time-resolved circular dichroism to the study of conformational changes in photochemical and photobiological processes, Journal of Photochemistry and Photobiology A: Chemistry, Volume 204, (Issues 2–3, 20 May 2009, Pages 137-143), https://gargantua.polytechnique.fr/siatel-web/app/linkto/mICYYYUGfRY (June 22, 2022)
2. Wang, Q., Ge, S., Li, X., Qiu, J., Ji, Y., Feng, J., and Sun, D., 2019, Valley Carrier Dynamics in Monolayer Molybdenum Disulfide from Helicity-Resolved Ultrafast Pump–Probe Spectroscopy, ACS Nano 2013, (7, 12, 11087–11093), https://pubs-acs-org.proxy.scejournals.org/doi/10.1021/nn405419h (June 22, 2022)
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4. Schmid, M., Martinez-Fernandez, L., Markovitsi, D., Santoro, F., Hache, F., Improta, R., and Changenet, P., 2019, Unveiling Excited-State Chirality of Binaphthols by Femtosecond Circular Dichroism and Quantum Chemical Calculations, J. Phys. Chem. Lett. 2019, 10, (14, 4089–4094), https://pubs.acs.org/doi/abs/10.1021/acs.jpclett.9b00948 (June 22, 2022)
5. Berera, R., Grondelle, R.V., and Kennis, J.T.M., 2009, Ultrafast transient absorption spectroscopy: principles and application to photosynthetic systems, Photosynth Res. 2009, (101(2-3), 105–118), https://link.springer.com/article/10.1007/s11120-009-9454-y (June 22, 2022)

Additional information:

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The five Nanoscale Science Research Centers (NSRCs) are DOE's premier user centers for interdisciplinary research at the nanoscale, serving as the basis for a national program that encompasses new science, new tools, and new computing capabilities. Each center has particular expertise and capabilities in selected theme areas, such as synthesis and characterization of nanomaterials; catalysis; theory, modeling and simulation; electronic materials; nanoscale photonics; soft and biological materials; imaging and spectroscopy; and nanoscale integration. These laboratories contain clean rooms, nanofabrication resources, one-of-a-kind signature instruments, and other instruments not generally available except at major user facilities. NSRC resources and capabilities are available to the international academic, industry and government research community for successfully peer-reviewed research projects.
For more information see:
https://science.osti.gov/bes/suf/User-Facilities/Nanoscale-Science-Research-Centers
NSRC Portal: https://nsrcportal.sandia.gov/

C55-10 ADVANCED ELECTRON MICROSCOPY – PRECISION CONTROLS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Advances in nanomaterials characterization through transmission electron microscopy (TEM) rely on precise control and stability of both sample stage and electron beam movements. Monitoring dynamic processes in beam-sensitive nanomaterials requires the development of sophisticated hardware and computational schemes to enhance data acquisition speed, improve temporal resolution, and minimize beam damage. The subtopics below illustrate two applications for which precision mechanical and electrostatic controls coupled to software/computational methods are sought. Development of these methods will enable *in situ* 2D and 3D atomic-scale investigations of energy-relevant materials, in real time and far from equilibrium.

Grant applications are sought in the following subtopics:

a. Sample Stage for Fast, Continuous Tomography in *In Situ* Transmission Electron Microscopy
Electron tomography reconciles the high imaging resolution of two-dimensional TEM projections with the need for reconstructing structural information in three dimensions. Recently, tomography has been extended to *in situ* experiments, in which the TEM sample is continuously rotated while undergoing thermal annealing, electrical biasing, gas exposure, mechanical testing, or other dynamic processes. The sample can either tilt back and forth over a large tilt angle, or continuously revolve in the same direction. Advances in continuous tomography are hindered by the rate of data acquisition/processing and the need for precise control of the sample position. This subtopic seeks combined hardware and software solutions to address the following challenges: a) improve time resolution without reducing the amount of 3D information recovered, b) develop precise automated stage controls to keep the sample centered in the field of view, at or near the eucentric height. The proposed tomography hardware should be compatible with commercially available devices for controlling the sample's environment, such as Micro-Electromechanical Systems (MEMS) chips providing heating or biasing.

Questions – Contact: Claudia Cantoni, claudia.cantoni@science.doe.gov

b. Electrostatic STEM Position Control
In current Scanning Transmission Electron Microscopy (STEM) experiments, the focused electron beam is scanned over a sample using electromagnetic coils. These scan systems provide high stability but are limited to microsecond-scale motion of the STEM probe due to their slow rise times. This means that jumping from one location on a sample to a non-adjacent region, or performing a scan pattern that is not continuous in space, is

not currently possible. Next-generation STEM scanning controls will enable many new classes of experiments: 1) non-adjacent scanning patterns, which have been shown to dramatically reduce damage for many beam-sensitive samples; 2) dynamic or adaptive scanning, where the position of the STEM probe is updated based on the current state of knowledge of the sample; 3) multiplexed measurements, where multiple probe locations can be recorded simultaneously for spectroscopic or diffraction imaging, and then separated later using computational methods such as compressed sensing, in order to improve measurement time resolution; 4) scanning multiple regions of a sample simultaneously for in situ experiments. This subtopic seeks the development of an electrostatic STEM scanning system using high-speed electronics and electrostatic deflectors. Ideally, this system will allow the STEM probe to be moved to any location on the sample with sub-microsecond travel times.

Questions – Claudia Cantoni, claudia.cantoni@science.doe.gov

c. Other

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

Questions – Contact: Claudia Cantoni, claudia.cantoni@science.doe.gov

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Additional information:
The five Nanoscale Science Research Centers (NSRCs) are DOE's premier user centers for interdisciplinary research at the nanoscale, serving as the basis for a national program that encompasses new science, new tools, and new computing capabilities. Each center has particular expertise and capabilities in selected theme areas, such as synthesis and characterization of nanomaterials; catalysis; theory, modeling and simulation; electronic materials; nanoscale photonics; soft and biological materials; imaging and spectroscopy; and nanoscale integration. These laboratories contain clean rooms, nanofabrication resources, one-of-a-kind signature instruments, and other instruments not generally available except at major user facilities. NSRC resources and capabilities are available to the international academic, industry and government research community for successfully peer-reviewed research projects.
For more information see:
https://science.osti.gov/bes/suf/User-Facilities/Nanoscale-Science-Research-Centers
NSRC Portal: https://nsrcportal.sandia.gov/

C55-11 ENHANCEMENT OF SCATTERING INSTRUMENTATION TECHNOLOGY USED AT PULSED AND CONTINUOUS NEUTRON SOURCES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Thermal and cold neutron scattering is a technique that provides unique information about materials due to the uncharged nature of the neutron, while still maintaining sensitivity to magnetic structures and different isotopes of the same chemical element. This topic seeks the development or improvement of equipment that would ultimately enhance neutron instrumentation capabilities towards meeting those goals at existing neutron sources. Additional information about neutron sources can be found here. Developments should improve performance by increasing measured signal-to-noise, on-sample beam flux, or measurement resolution, or provide a novel capability that will enable new techniques at those neutron sources.

Grant applications are sought in the following subtopics:

a. Large-scale Fabrication of Super-mirror Reflection Surfaces for Neutron Guides, Mirrors and Filters
A domestic manufacturer is sought to develop the capability to fabricate and deliver neutron super-mirror guides and associated neutron optics systems. Thin-film Nickel/Titanium nano-composite coatings on glass, silicon and metallic substrates are used to construct enclosed guide systems and singular and compound mirrors, as well as energy-dependent reflectors and filters. High-quality components of this kind are essential to prepare incident neutron beams for new and upgraded instruments at user-focused scattering facilities anticipated in the next five to ten years. Key requirements are:

i. Coated surfaces should be able to reflect neutron wavelengths of 2.0 Å up to 0.8^{o} (m=4) grazing-incident angle with reflectivity greater than 80%.
ii. Typical guide cross-section dimensions range from 4 cm to 15 cm, with complete segmented systems as long as 100 meters.
iii. Guide systems can be split into multiple channels for optical or compact design purposes.
iv. The volume within any enclosed guide should be able to maintain vacuum < 1 mbar or backfilled with Helium. Non-enclosed optics must be able to reside in an evacuated or backfilled enclosure.

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

b. Compact, Portable Single-Crystal Neutron Diffractometer

Modern advances in thermal neutron detectors, neutron optics, automated controls and sample cooling systems have enabled the possibility to develop a compact single-crystal neutron diffraction system using off-the-shelf equipment in a way that is comparable to already commercially available single-crystal XRD systems. Proposed concepts should focus on delivery of a system that can be installed at an existing neutron source, is simple to install, calibrate, and operate, and includes software for automated, programmable control and crystallographic structure refinement. Such a system should also have a large solid-angle coverage and operate in either Laue or time-of-flight modes to permit use at a reactor or pulsed source. Built-in sample cooling and a suitable crystal orientation capability will be required to efficiently gather the entire set of reflections for structure refinement. Samples of interest for this application would be small in volume with unit cell edge lengths supporting macromolecular crystallography, although systems targeting smaller unit cells for quantum condensed matter are also encouraged. Key requirements are:

i. Solid-angle coverage on the order of 2π steradians (50% of a full sphere).
ii. Laue mode operation and ability to use an external timing signal permitting use at a reactor or pulsed source for time-of-flight operation.
iii. Provide sample cooling below 77 K.
iv. Crystal orientation capability that provides full reflection coverage given the detector geometry.
v. Provide fully integrated, automated, and programmable operation.
vi. Sample volumes as small as 1 mm^3 and resolve a range of unit cell lengths up to 100 Å, although systems designed for smaller cell edge sizes as low as 3 Å are still encouraged.

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

c. High Rate, High Resolution Imaging Data Acquisition and Processing

Neutron and X-ray Radiography has recently been shown to provide information about materials and equipment that cannot be quantified by any other means. Accelerator-based user facilities are developing dedicated polychromatic radiography beamlines to support exactly that need. This requires imaging resolution on the order of 10 microns with time resolution on the order of 1 nanosecond across a detector that can be as wide as 20 cm. While there are ASICs that can meet the resolution requirements, a large, tiled area of those in conjunction with additional position calculations will be required in order to meet the demands of radiography applications. The event rates for a radiography system at a pulsed neutron source can be 10^8 counts per second or higher depending on the beam conditions. A board-based processing solution is needed to take the data directly from the photo-sensitive chips and process it into appropriate position and time-of-flight information, reducing the overall data rate. The processed output would then be transmitted through a traditional connection capable of handling the new "condensed" data stream for further distribution to an existing data acquisition and control system. Specific requirements are:

i. A system capable of interfacing with 48 standard photo-sensitive hybrid ASICs with total data rate as high as 492 Gbps.
ii. Neutron event processing rates exceeding 100 MHz.
iii. A remotely accessible interface for setup, maintenance, and calibration of the system.
iv. An output interface that utilizes standard signal line technologies (such as IEEE 802.3cu-2021) in order to support high data rates.
v. A data output standard that is compatible with existing instrument acquisition systems.

Questions – Contact: Eliane Lessner, Eliane.Lessner@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 descriptions above.

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

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C55-12 HIGH PERFORMANCE MATERIALS FOR NUCLEAR APPLICATION

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

To achieve energy security and clean energy objectives, the United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible. Nuclear power will continue to be a key component of a portfolio of technologies that meets our energy goals. Nuclear Energy R&D activities are organized along four main R&D objectives that address challenges to expanding the use of nuclear power: (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; (2) enable the deployment of advanced reactors to help meet the Administration's energy security and clean energy goals; (3) develop sustainable nuclear fuel cycles; and (4) maintain US leadership in nuclear energy technology.

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

Please note: following award, all DOE SBIR/STTR grant projects requiring high performance computing support are eligible to apply to use the DOE National Energy Research Scientific Computing Center (NERSC) resources. NERSC is the primary scientific computing facility for the DOE. If you think you will need to use the

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computing capabilities of NERSC during your Phase I or Phase II project, you may be eligible for this free resource. Learn more about NERSC and how to apply for NERSC resources following the award of a Phase I or Phase II project at http://www.nersc.gov/users/accounts/allocations/request-form/.

Grant applications are sought in the following subtopics:

a. Bimetallic Structures for Liquid-Cooled, High Temperature Reactor Systems

Advanced high temperature nuclear reactor systems may utilize liquid coolants to optimize heat transfer, neutronics, safety, and compactness of the nuclear supply system. Examples of such systems in which corrosion is a particular challenge are liquid-salt cooled reactors (both those in which the fuel is fixed and those where it is dissolved in the coolant) and lead- (or lead-bismuth) cooled reactors. In each of these reactors, the structural components of the primary systems in contact with the reactor coolant must be adequately compatible with the materials of the reactor components. While materials permitted for construction of high-temperature components of nuclear reactors are specified in Section III Division 5 of the ASME Boiler and Pressure Vessel Code, they may not provide adequate corrosion resistance with respect to the liquid coolants described for long corrosion lifetimes.

One alternative is to develop bimetallic structures consisting of a corrosion-resistant surface layer (e.g., weld overlay cladding, roll bonding, etc.) and a structural substrate approved for use in ASME Code Sec III Div 5. Grant applications are sought to develop such a system with emphasis on fabrication methods (including for complex 3-D structures) and projected metallurgical stability over an extended component lifetime (> 20 years). Corrosion, aging, diffusion-related changes in composition, and thermo-mechanical loading should be considered. Note: Thin coatings will not be considered due to high likelihood of peeling, spalling, scratching, debonding, etc., over long component lifetimes.

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

b. Powder Metallurgy-Hot Isostatic Pressing of High Temperature Metallic Alloys

Advanced manufacturing (AM) technologies can play an important role in reducing the fabrication costs of fission reactor components. Powder Metallurgy-Hot Isostatic Pressing (PM-HIP) shares many of the cost-saving attributes of the other AM methods such as powder bed fusion and directed energy deposition. Also, PM-HIP is a competitive and proven AM technology that is used in many non-nuclear industries to fabricate structural components. It can be readily deployed for advanced reactor applications. However, recent tests conducted on PM-HIP structural materials showed that while the mechanical properties are comparable to or better than wrought product at low temperatures, the high-temperature cyclic performance is less favorable. This is a challenge for advanced reactor applications, as creep-fatigue damage due to thermal transients from reactor operations is the most severe structural failure mode. The cause of the degradation in cyclic properties is currently not known, but it could be due to powder compositions, oxygen content, processing conditions, etc.

Applications are sought to develop an improved PM-HIP process for high-temperature alloys, including powder chemistry specification, powder manufacturing, container manufacturing, container filling and outgassing, hipping parameters, container removal, etc., so that the high-temperature fatigue, creep, and creep-fatigue properties of the fabricated components are the same as or exceed those of wrought product for very long design lifetimes.

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

c. Simultaneous Measurement of Density and Viscosity for High-Temperature Molten Salts

High-temperature molten chlorides and molten fluorides are used as a liquid fuel medium and as a heat transfer fluid in several advanced reactor systems as well as heat storage and heat transfer fluids for concentrated solar power. These low-viscosity molten salts typically have a viscosity < 10 cP (< 0.01 Pa·s) depending on temperature and composition. Both the design and operation of these systems require viscosity and density measurements of the chosen salt system as a function of composition and temperature. Presently, a database of thermophysical properties of molten salts is being compiled from literature data as well as from new experimental measurements to support the design of molten salt-based systems. The concerted effort to make new measurements would benefit from new accurate high-throughput devices capable of measuring viscosity and density of high-temperature molten salts as a function of temperature. Operation of these molten salt systems typically involves pumping molten salts through heat exchangers and therefore would benefit from a real-time in-line or at-line device for measurement of density and viscosity of molten chloride and molten fluoride salts. These laboratory and monitoring devices must be capable of making high-precision measurements of viscosity and density at temperatures up to 800°C. For reactor applications the devices must not be affected by ionizing radiation. Possible viscosity and density measurement techniques that could be adapted to high-temperature measurements of viscosity and density include vibrating cantilevers[7] and microfluidic-based methods.[8]

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

d. Other

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

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

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C55-13 ADVANCED SUBSURFACE ENERGY TECHNOLOGIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Next-generation advances in subsurface technologies will enable access to more than 100 gigawatt-electric (GWe) of clean, renewable geothermal energy, as well as safer development of domestic oil and gas supplies. The subsurface can also serve as a reservoir for energy storage for power produced from intermittent generation sources, such as wind and solar. As such, understanding and effectively harnessing subsurface resources while mitigating impacts of their development and use are critical pieces of the Nation's forward energy strategy.

The Department of Energy's (DOE) Office of Basic Energy Sciences (BES) teams with the Geothermal Technologies Office (GTO) and Office of Fossil Energy and Carbon Management (FECM) in order to advance the state of the art for continued development of subsurface energy sources in a safe and sustainable matter through the focus areas and subtopics listed below.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Grant applications are sought in the following subtopics:

a. Geothermal

This subtopic focuses on geothermal systems hosted in sedimentary systems, which directly supports the Biden Administration's goals for a clean energy future. In order to advance the state of the art for such potential geothermal systems, the Department of Energy's Office of Basic Energy Sciences and Geothermal Technologies Office have teamed together to support R&D in the subtopic below. The goal of this subtopic is to advance innovation in development of sedimentary rock formations that may be used to host geothermal systems for purposes of producing electricity.

Applications of interest under this subtopic should focus on the challenges related to improving technologies related to geothermal energy development in conditions with elevated temperatures (> 390°F or approximately 200°C) within sedimentary lithologies in order to gain understanding on utilizing sedimentary systems (versus traditional geothermal crystalline systems) for purposes of geothermal energy production. Applications of interest may include, but are not limited to, the following:

- Novel approaches to characterize subsurface physical and chemical changes in porous rock-fluid systems.
- Development of new methodologies to understand porosity and permeability trends related to well stimulation.
- Innovative wellbore designs that focus on utilizing heat contained in sedimentary rock stratigraphy.

A Phase I application should focus on proof of concept via engineering design, materials development, modeling, and/or laboratory scale testing (as applicable). Phase I efforts should be scalable to subsequent Phase II development including model validation, prototype development, and/or pilot or field-scale testing (as applicable).

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Proposed projects with modeling or analysis components could propose analysis of new data sets, existing data sets within the Geothermal Data Repository (GDR) at https://gdr.openei.org/, or other existing data sets. DOE is seeking as much emphasis on open-source data and/or methods as possible.

Applications must be responsive to the subtopic of improving understanding of utilization of potential sedimentary resources for purposes of creating electricity from geothermal energy. Applications focusing on crystalline lithologies, conventional ground source heat pumps, traditional direct-use applications, gathering of data via downhole sensors, and conventional usage of geothermal fluids coproduced with hydrocarbons via additional or modification of surface-based equipment will be deemed non-responsive.

Questions – Contact: William Vandermeer, william.vandermeer@ee.doe.gov

b. Development of Wellbore Repair and Remediation Systems for a Gigaton Carbon Storage Industry

DOE's Carbon Transport and Storage Program seeks novel, cost-effective wellbore integrity repair and remediation systems. The integrity of wellbores – specifically the integrity of casing and materials (cement) used to seal the annulus between the casing and the formations – is essential to ensure safe and reliable injection operations as well as long-term containment of CO_2 in the targeted reservoir. Wellbore materials must be resistant to chemical corrosion from contacting fluids, be sufficiently strong to withstand mechanical stresses associated with injection, and form complete hydraulic isolation to ensure containment. The acidic nature of carbonic acid (CO_2 dissolved into brine) creates a risk unique to carbon storage projects. Carbon steel well components and Portland cements used in conventional oilfield operations can both be breached by the low pH of the fluid. Wellbores potentially requiring repair and remediation include: operating wellbores constructed as part of the development of a storage project; pre-existing wellbores that might be repurposed for injection or monitoring; and abandoned wellbores which may not be easily re-entered, and/or may have been previously plugged and abandoned.

Grant applications are sought for the development of an innovative and cost-effective repair and remediation system for commercial use that provides a much higher success rate than the industry standard. The repair and remediation system should include the materials for repair and remediation, the tools to emplace the materials, and tools and methods to assess the integrity of the repair and remediation. Materials must have chemical resistance, strength, and hydrologic properties suitable to enable secure CO_2 storage. In addition, materials for repair and remediation of the wellbore annulus must be able to seal a variety of potential CO_2 migration pathways from micro- to macro-scale. There are a wide variety of repair and remediation actions, which will likely involve different materials, emplacement, and assessment methods. Grant applications should describe the specific repair and remediation actions which can be performed by the proposed system.

Questions – Contact: Sarah Leung, sarah.leung@hq.doe.gov

c. Turn-Key Service to Create a Geophysical (Electrical and/or Electromagnetic Methods) Monitoring Network for Use During Carbon Storage Site Characterization and/or Carbon Storage Operations

The carbon storage program has focused on developing processes and tools that can accurately and affordably assess seismicity risk and CO_2 migration risks prior to the CO_2 injection phase of a commercial-scale carbon capture and storage operation (>1 million metric tons per year) and/or assess the CO_2 plume location after commercial storage operations have started. In the initial phase of a project, there is a strong need to identify natural fracture flow pathways leading into the deeper crystalline basement or into shallower rock layers. The idea is to identify high-risk sites before making large investments in developing the storage project. During the injection of CO_2, there is a need to map the location of the plume of injected CO_2 within the storage reservoir and identify any CO_2 fluid flows into shallower permeable strata where smaller CO_2 plumes may form. Recently, DOE's SBIR program solicited turn-key passive seismic monitoring networks and services.

Here a new SBIR subtopic solicits for deep subsurface interrogation and geophysical monitoring networks deploying electrical and/or electromagnetic methods, whereby a balance is sought between a fit-for-purpose number and placement of any necessary electric (E) and/or magnetic (B) field sensors along with the sensitivity, frequency range (if applicable), and types of sensors for accurate detection of very weak electrical and electromagnetic field anomalies and CO_2 plumes. These networks would include an intelligent level of data processing and streamlined interpretation that does not create a burdensome task for carbon storage project developers and operators. Because geophysical monitoring remains an important factor across the project lifecycle (prior to, during, and after CO_2 injection), an additional consideration should be placed on the robust and rugged nature of the system design to support deployment over months to more than 30 years, with an outlook that the system could be updated or upgraded for further use in later phases of the project.

Joint inversion of time-lapse seismic data with electrical and gravimetric measurements is widely believed to be a superior method for mapping and quantifying CO_2 plumes in sedimentary rock strata. Because injected CO_2 may initially push native brines upwards through seal layers into overlying permeable rock layers, the increased electrical conductivity of higher-salinity brines intruding into low-salinity brines could be detectable, even mappable in some cases. Alternatively, interconnected natural fractures in networks extending into the basement may conduct electrical currents into strata that are otherwise more electrically resistive, such that weak EM field anomalies may be detectable. While joint inversion is not within the scope of this subtopic area, the monitoring network should be designed to allow for data acquisition supporting this activity.

Grant applications are sought for turn-key systems and services that facilitate easier, better, higher-resolution data acquisition and interpretation of seismicity risks, CO_2 migration risks, and/or CO_2 plume location(s) using one or more electrical resistivity (ER), magnetotelluric (MT), self potential (SP), and/or electromagnetic (EM – natural- or controlled-source) monitoring networks, during the site characterization phase, commercial operations phase, and/or post-injection site care phase, for a broad range of site conditions, either onshore or offshore.

To enable this step increase, the goal is to develop a turnkey service that will deliver to the customer a site-specific monitoring system design, followed by installation of the complete monitoring system, coupled with a tailored level of processing and right-sized data storage and archiving (which is readily accessible by the storage-site developer or operator). Applicants should consider the cost effectiveness of combining more than one electrical geophysics method, and the potential for joint inversion of electromagnetic data with seismic and gravity data (although seismic and gravity methods are not directly within the scope of this subtopic area, nor are the methods of electrical or electromagnetic data interpretation or joint inversions).

Sensors or sources can be placed at the land surface or on the sea floor, in shallow boreholes or, on a limited basis, in deep boreholes, and may be deployed in conjunction with other geophysical sensors (e.g., seismic or gravimetric). Sensors may also be towed through the air, across the land surface, or through/upon water bodies. Electromagnetic fields may be induced, and electrical currents may be injected or induced and may be sourced naturally, anthropogenically, or both. Energetic downhole electromagnetic sources that can be deployed in steel-cased wells, fiberglass-cased well sections, or open-hole sections are of interest. Choice of orientation of the monitoring network should account for the orientation of the electrically resistive/conductive features to be assessed. Methods that are minimally disruptive to surface owners and current land use are preferred. Data interpretation may depend on *a priori* geologic models, borehole data, interpreted seismic data or other constraints; however, the inverse problem must be solvable for a volume of rock large enough to be of value in addressing the concerns identified above for a commercial-scale, geologic CO_2 storage complex. The focus of this funding opportunity is not the development of hardware or software; however, hardware and software development can be a small part of the project (a future solicitation may fund such developments further). Nor is this funding opportunity for the development of "imaging" software; however, this can be a small part of the project. Separately, under the SMART Initiative, DOE is developing methods and software for converting (and jointly inverting) raw to semi-processed data streams in near real time into visualizations of subsurface conditions.

Questions – Contact: Sarah Leung, sarah.leung@hq.doe.gov

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C55-14 ADVANCED FOSSIL ENERGY AND CARBON MANAGEMENT TECHNOLOGY RESEARCH

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Office of Fossil Energy and Carbon Management (FECM) Research, Development, Demonstration, and Deployment (RDD&D) program conducts research that focuses on early-stage technologies that help to ensure clean and affordable energy for all Americans, facilitate the transition towards a carbon-pollution-free economy, rebuild a U.S critical minerals (CM) supply chain, and retain and create good paying jobs with a free and fair chance to join a union and collectively bargain. FECM's priorities include: Reduce Methane Emissions; Accelerate Carbon-Neutral Hydrogen (H2): Develop Low-Carbon Supply Chains for Industries; Advance Carbon Dioxide Removal Technologies; Invest in Thoughtful Transition Strategies to a net-zero carbon economy in coal and fossil-based power plant communities; Demonstrate and Deploy Point Source Carbon Capture and Storage to meet net-zero emissions goals by 2050; Advance CM, Rare Earth Elements (REE), Coal Waste to Products and Mine Remediation; Increase Efficient Use of Big Data and Artificial Intelligence (AI); Address the Energy Water Nexus.

Please note: following award, all DOE SBIR/STTR grant projects requiring high performance computing support are eligible to apply to use the DOE National Energy Research Scientific Computing Center (NERSC) resources. NERSC is the primary scientific computing facility for the DOE. If you think you will need to use the computing capabilities of NERSC during your Phase I or Phase II project, you may be eligible for this free resource. Learn more about NERSC and how to apply for NERSC resources following the award of a Phase I or Phase II project at http://www.nersc.gov/users/accounts/allocations/request-form/.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Grant applications are sought in the following subtopics:

a. Advanced Technology Development of High Purity Oxygen Separation from Air

The Gasification Systems Program, conducted under the U.S. Department of Energy's Office of Fossil Energy and Carbon Management (FECM), is developing innovative, flexible, and small-scale, modular systems for converting diverse types of wastes such as waste plastics, municipal solid waste (MSW), waste biomass, and waste coal into clean hydrogen with carbon capture and storage to achieve net-zero carbon emissions [1,2]. The small-scale modular systems offer distinct advantages against big commercial scales, expediting technology development, cutting capital investment and operating costs, improving availability, and offering flexibility in meeting location-specific needs.

Since gasification is the partial oxidation of combustible materials and operates in an oxygen-lean environment, oxygen can be provided by either air or high-purity oxygen produced by an oxygen separation unit from air. Air-blown gasifiers avoid the large capital cost of an oxygen separation from air but produce a much lower hydrogen content after WGS (water gas shift) reactions than oxygen-blown gasifiers due to nitrogen in air. Air-blown gasifiers also have much bigger systems than oxygen-blown gasifiers due to high volume of nitrogen in air. Because of the dilution effect of the nitrogen, the partial pressure of CO_2 in air-blown gasifier syngas will be one-third of that from an oxygen-blown gasifier. This increases the cost and decreases the effectiveness of the CO_2 removal. Commercially available cryogenic distillation-based oxygen separation from air is costly and energy-intensive, and these systems cannot be scaled down cost-effectively because of huge balance of plant costs. Development of an innovative technology for oxygen separation from air for use in small-scale, modular gasification systems is encouraged to increase deployment opportunities.

Grant applications are sought for research and development of innovative systems to generate high-purity oxygen (above 95%) from air that can show significant capital cost reduction compared with commercial/conventional cryogenic distillation-based oxygen separation technology. Areas of interest are limited to any technology whose operation temperature is lower than 150°C (302°F). However, electrochemical membrane, MOF (metal-organic framework), distillation-based technologies, polymer membrane technologies, and magnetic technologies will not be accepted.

The applicant must provide how their proposed technology would reduce capital cost and improve performance to obtain at least 95% oxygen purity from air. Phase I effort should demonstrate the feasibility of the concept in lab-scale testing. Phase II effort should demonstrate oxygen generation at pilot scale.

Questions – Contact: Jai-woh Kim, jai-woh.kim@hq.doe.gov

References:

1. National Energy Technology Laboratory, 2022, Gasification Systems, https://netl.doe.gov/carbon-management/gasification (June 22, 2022)
2. National Energy Technology Laboratory, 2022, Gasification – Yesterday, Today, And Tomorrow, https://netl.doe.gov/carbon-management/gasification/background (June 22, 2022)

C55-15 TECHNOLOGY TRANSFER OPPORTUNITIES: BASIC ENERGY SCIENCES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Applicants to TECHNOLOGY TRANSFER OPPORTUNITIES (TTO) should review the section describing these opportunities on page 8 of this document prior to submitting applications.

Grant applications are sought in the following subtopics:

a. Refractive Polymer-Based X-Ray Optical Components

To fully utilize the high coherence of DOE's diffraction-limited X-ray sources, there is an urgent need for a giant leap forward in the manufacturing capabilities of X-ray refractive optics that are required for controllable wavefronts in the applications of coherent-based experiment methods. To meet these goals, Argonne National Laboratory researchers have been developing a customizable strategy to manufacture and deploy polymer-based refractive X-ray optics at synchrotron beamlines (US Patent Pending 17/039,624). Using high-resolution polymerization lithography, refractive X-ray optics, such as phase correctors and compound refractive lenses (CRLs), can be rapidly and cost-efficiently printed with a better-than-100 nm printing resolution. These optics have shown a higher quality and better performance than conventional lenses, such as commercially available Beryllium CRLs. Supported on the small flat substrates, these lenses can be quickly deployed into an X-ray beam delivery system. The researchers also devised the transfocator-on-chip, a device comprising printed arrays of CRLs on a single substrate to meet various focusing requirements. These transfocators-on-chip have much more compact form factor and are more affordable than conventional transfocators.

ANL is looking for industrial partners to commercialize this technique rapidly for wide applications in various synchrotron facilities and other X-ray delivery systems. The joint advanced R&D will focus on the following aspects:

i. Improve multiple polymerization printing lithography schemes for better lens quality and shape controls.
ii. Improve the printing resolution to 20-50 nm.
iii. Scale-up the procedure for high-throughput optics fabrication, aiming at a useful lens array set per one to a few hours.
iv. Investigate high-energy (>20 kev) and high-coherence applications of printed optics.
v. Design commercialization-ready assembly scheme for stand-alone instrument that allows fast optics alignment and flexible operation to meet various experimental requirements at synchrotron beamlines.
vi. Develop a cost-effective transfocator mechanism for rapid lens exchange and replacement.

Licensing Information:
Argonne National Laboratory
Contact: Cecilia Gentle, cgentle@anl.gov, (630) 252-6754
ANL Technology ID: IN-20-070
Patent Status: US Patent pending 17/039,624

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

References:

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PROGRAM AREA OVERVIEW: OFFICE OF BIOLOGICAL AND ENVIRONMENTAL RESEARCH

The mission of the Biological and Environmental Research (BER) program is to support transformative science and scientific user facilities to achieve a predictive understanding of complex biological, earth, and environmental systems for energy and infrastructure security and resilience. The program seeks to understand the biological, biogeochemical, and physical principles needed to fundamentally understand and be able to predict processes occurring at the molecular and genomics-controlled smallest scales to environmental and ecological processes at the scale of planet Earth. Starting with the genetic information encoded in organisms' genomes, BER research seeks to discover the principles that guide the translation of the genetic code into the functional proteins and metabolic and regulatory networks underlying the systems biology of plants and microbes as they respond to and modify their environments. Gaining a predictive understanding of biological processes will enable design and reengineering of microbes and plants for improved energy resilience and sustainability, including improved biofuels and bioproducts, improved carbon storage capabilities, and controlled biological transformation of materials such as nutrients and contaminants in the environment. BER research also advances the fundamental understanding of dynamic, physical, and biogeochemical processes required to systematically develop process and Earth system models that integrate across the atmosphere, land surfaces, oceans, sea ice, coasts, terrestrial ecosystems, watersheds and subsurface required for predictive tools and approaches responsive to future energy and resource needs.

BER has interests in the following areas:

(1) Biological Systems Science subprogram carries out basic research to underpin development of sustainable bioenergy production and to gain a predictive understanding of carbon, nutrient, and metal transformation in the environment in support of DOE's energy and environmental missions. Genomic Science research is multifaceted in scope and includes a complementary set of activities in basic biological research focused on DOE's efforts in bioenergy development. The portfolio includes the DOE Bioenergy Research Centers (BRCs), team-oriented research within the DOE National Laboratories and focused efforts in plant feedstocks genomics, biosystems design, sustainability research, environmental microbiology, computational bioscience, and microbiome research. These activities are supported by a bioimaging technology development program and user facilities and capabilities such as the Joint Genome Institute (JGI), a primary source for genome sequencing and interpretation, the DOE Systems Biology Knowledgebase (KBase) for advanced computational analyses of "omic" data and, instrumentation at the DOE synchrotron light and neutron sources for structural biology. The research is geared towards providing a scientific basis for producing cost effective advanced biofuels and chemicals from sustainable biomass resources.

(2) Earth and Environmental Systems Sciences Division (EESSD) activities include fundamental science and research capabilities that enable major scientific developments in Earth system-relevant atmospheric and ecosystem process and modeling research in support of DOE's mission goals for transformative science for energy and national security. This includes research on components such as clouds, aerosols, terrestrial ecology, watersheds, terrestrial-aquatic interfaces, as well as modeling of component interdependencies under a variety of forcing conditions, interdependence of climate and ecosystem variabilities, vulnerability, and resilience of the full suite of energy and related infrastructures to extreme events, and uncertainty quantification. It also supports terrestrial ecosystem and subsurface biogeochemical research that advances fundamental understanding of coupled physical, chemical, and biological processes controlling energy byproducts in the environment. The subprogram supports three primary research activities, two national scientific user facilities, and a data activity. The two national scientific user facilities are the Atmospheric Radiation Measurement Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL). ARM provides unique, multi-instrumented capabilities for continuous, long-term observations and

model-simulated high-resolution information that researchers need to develop and test understanding of the central role of clouds and aerosols on a variety of spatial scales, extending from local to global. EMSL provides a wide range of premier experimental and computational resources for studying the physical, biogeochemical, chemical, and biological processes that underlie DOE's energy and environmental mission. The data activity encompasses observations collected by dedicated field experiments, routine and long term observations accumulated by user facilities, and model generated information derived from Earth models of variable complexity and sophistication.

For additional information regarding the Office of Biological and Environmental Research priorities, visit https://science.osti.gov/ber/Research.

C55-16 URBAN MEASUREMENT TECHNOLOGY

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Earth and Environmental Systems Sciences Division (EESSD) within the Biological and Environmental Research (BER) program has recently initiated a new focus on urban regions through development of an Urban Integrated Field Laboratories research effort (References 1-3). EESSD's objective for its urban research initiative is to advance the science underpinning understanding of the predictability of urban systems and their two-way interactions with the climate system and to provide the knowledge and information necessary to inform equitable climate and energy solutions that can strengthen community scale resilience across urban landscapes. As part of this focus on urban research, BER has identified the need for improved measurement technologies for urban regions.

This topic is focused on addressing measurement and data challenges to improve the spatial characterization of key atmospheric, ecological, and environmental variables across urban regions. Urban regions are densely populated areas and are highly heterogeneous, i.e., having uneven distribution of physical landforms and vegetation, environmental processes, the built environment and infrastructure, population density, and socioeconomic clustering in the urban landscape. These complex, heterogeneous environments make representative measurements of urban regions and systems challenging.
Some of the challenges of urban observations include: measurements conducted at a single location may not be representative of other areas in the urban region; properties and characteristics are likely to change rapidly over short distances and times and may be influenced by anthropogenic flows and sources of emissions, heat, and water; measurement techniques may not be designed for the variable surfaces and complex atmospheric flows experienced in urban areas; sensors need to be robust, self-cleaning, low powered, resistant to tampering; and that data from disparate sources may need to be integrated to get a full view of the urban system (References 4-6).

Particular emphasis is placed on technologies that can provide information on spatial variabilities across urban regions and how the variabilities exert influences on local micro-climates and micro-environments affecting urban communities or that can provide observations for understanding biogeochemical cycling and atmospheric composition in urban systems. Of particular interest are individual or networked systems suitable for unattended and/or remote operation and that have independent/low power requirements and on-board or centralized/remote data storage and download capability for extended unattended operation and data collection.

Applications to this topic could include: new measurement sensors or instrument systems; new algorithms for improved measurements in urban environments with existing sensors; low-cost or adaptable sensors that could be deployed in distributed networks or mounted on surface vehicles; methods to combine in situ and satellite data to better characterize urban regions; methods for enabling and analyzing non-traditional data sources such as crowd-sourced, mobile phone, vehicle, or community-based observing data; or new data products or visualization tools that merge data from multiple sensors.

Applications to this topic that propose development or improvement of hardware should (1) demonstrate performance characteristics of the proposed technology, and (2) show a capability for deployment in urban environments. Phase I projects must perform feasibility and/or field tests of proposed technologies to assure the ability to survive the complex physical and human conditions common to an urban environment. Applications must provide convincing documentation (experimental data, calculations, and/or simulations as appropriate) to show that the proposed method is appropriate to make the desired measurements and can feasibly be deployed in urban environments without violating rules, regulations, and laws, including privacy concerns.

Applications proposing development of data products or visualization tools that merge data from multiple sensors must clearly explain the availability of the data to be used. Applications proposing collection of data from non-traditional sources (e.g., crowd-sourced, mobile phone, vehicle, or community-based observing data) must clearly explain the feasibility of collecting the proposed data, and how collection of such data will be done without violating rules, regulations, and laws, including privacy concerns.

Applicants are encouraged to consider novel and innovative approaches. Applications must clearly indicate how the proposed technology is a significant advance over existing commercially available technologies, data products, or tools for the measurement variables of interest. Applications that propose only incremental improvements to existing sensors, data products, or tools may be declined. Applications should clearly describe planned calibration, verification, and/or quality control procedures for any proposed instrument, sensor, or data product.

EXCLUSIONS/RESTRICTIONS:
Applications that include development of uncrewed aerial system (UAS) platforms, autonomous ground vehicles, autonomous aquatic vehicles, or sensors or control systems for such autonomous vehicles are not responsive and will not be accepted.

a. Urban Atmospheric Characterization
This subtopic solicits applications for novel and innovative measurement technologies for improved characterization of the spatial distribution of atmospheric properties in the urban boundary layer with a particular focus on boundary layer height, atmospheric turbulence, vertical wind profiles, aerosol composition, aerosol absorption, and aerosol size distribution.

High spatial and temporal-resolution measurements of the boundary layer height, atmospheric turbulence, and vertical profiles of atmospheric wind speed and direction within and around urban regions are important for understanding transport and dispersion of atmospheric pollutants, the maintenance of the urban heat island, and large-scale flow within and around cities (References 7-8). Additionally, such profiles are needed for initializing and validating high-resolution urban models (Reference 9). The heterogeneity of the urban environment makes it challenging to characterize atmospheric flow features such as dead zones, eddies, and flow through street canyons and around built and natural structures in urban areas (Reference 9). Existing measurement techniques such as radar wind profilers, Doppler lidars, scintillometry, and eddy covariance are increasingly being deployed in urban environments, but improvements in capabilities, size, power, cost, autonomous operation, reduced ground clutter, and portability are needed to make them more suitable for deployment as part of urban sensor networks (References 10-13). Additionally, improved methods for quality control, calibration, and interpretation of measured data over complex urban surfaces are needed (Reference 11).

In addition to measurements of quantities relevant to physical meteorology, measurements of aerosol properties are sought as well. Aerosol properties can vary significantly over short time and space scales in urban environments due to the variability of emission sources, transport and dispersion, and chemical transformations. Therefore, low-cost sensors capable of being deployed as sensor networks are needed to better characterize aerosol properties in urban environments (References 14-15). While many low-cost sensors for measurement of aerosol particulate mass currently exist, measurements of aerosol size distributions, absorption, and composition are typically performed by more complex instruments.

Applications are sought for development of low-cost, low-power sensors for aerosol particle size distribution, aerosol absorption, and/or aerosol composition that are suitable for unattended and remote operation in urban environments.

Applications must clearly indicate how proposed sensors are an advance over existing commercially available technologies or existing sensor networks (e.g., increased capabilities; significantly lower size, power or cost) and why the proposed sensors are more suitable than existing commercial technologies for measurements in urban environments.

Questions – Contact: Sally McFarlane, Sally.McFarlane@science.doe.gov or Jeff Stehr, Jeff.Stehr@science.doe.gov

b. Urban Hydrologic Measurements

This subtopic solicits applications for development of new and innovative measurements and approaches to better characterize the hydrology of urban stream networks, streamflow and inundation dynamics. An integrated understanding of urban watershed biogeochemistry and water, energy, and biogeochemical cycling in urban ecosystems requires detailed characterization of hydrological drivers. Urban hydrology is driven by hydraulically efficient but often deteriorating stormwater drainage, complex runoff and infiltration patterns created by urban land use, and the complexity of urban precipitation patterns. Urban flooding is a growing concern in urban regions due to increased development of impervious surfaces, deteriorating infrastructure and changing weather patterns (Reference 16). In addition to flooding the hydro-biogeochemical dynamics of urban streams are distinct and due to different processes than natural systems (e.g., urban stream syndrome [Reference 17]). Small urban streams are often "flashier" (e.g., higher variability in high and low flows), and subject to diversion, disconnection, and other channel alterations. They may disappear and reappear through urban landscapes and are often infrequently monitored or measured. They flow through restricted or exposed landscapes, making traditional stage and discharge measurements unrealistic or impossible.

Continuous monitoring of key urban streamflow characteristics (stage, discharge) and event-based detection and mapping of overland flow and inundation extent in urban systems are key challenges toward a systematic understanding of urban hydrology and how it impacts the function and structure of urban ecosystems and drives urban watershed hydro-biogeochemistry. Highly detailed and low latency hydrologic information can help inform study design and target sampling for urban watershed studies, and can provide key information on the causes, impacts, and potential mitigation of small urban stream flooding. Applications are sought for new approaches to continuous water level and discharge measurements in small urban streams, to address the challenges of characterizing urban stream networks. Applications to this topic should target continuous measurements of water level and/or discharge, and/or approaches to detecting and mapping inundation events (e.g., ponded or overland flowing water) and ephemeral channels in urban watersheds. Development of in situ streamflow sensors will need to meet the challenges with approaches that meet the challenges of hardened, inconspicuous, autonomous sensors needed to work in urban environments. Approaches for inundation, overland flow, and ephemeral channel flow either could be met through sensor development and/or non-contact or crowd source methods. Key characteristics for technologies to map and detect inundation and flowing water include technology that detects and communicates events in real time, an ability to withstand and record both inundation and recession of water, and hardened, inconspicuous, low-cost sensors that can deployed in arrays in urban environments to capture urban flooding dynamics in small streams.

Questions – Contact: Jennifer Arrigo, Jennifer.Arrigo@science.doe.gov

c. Urban Visualization and Data Analysis Tools

This subtopic solicits applications for novel and innovative visualization and data analysis tools to inform urban research, stakeholders and decision makers. Existing urban measurements are collected by a variety of agencies, organizations, and institutions and cover a wide range of data types, resolutions, and formats. Tools are needed to integrate, quality control, and visualize urban data sets from existing in situ networks, satellite data, models, and other non-traditional data sources to make them easier to access by research and user communities. Tools must extend beyond a single location or a single variable and must instead be applicable to multiple urban areas, measurements, and uses. Tools that consider the variable uncertainties of measurements and other data types are highly desired. Innovative tools that make use of machine learning, artificial intelligence, or advanced statistical techniques for merging multiple data sets, intelligent mapping, gap filling, downscaling, interpolation, or derivation of additional environmental parameters are of particular interest. Applications are strongly encouraged to consider development of tools that couple urban climate/environmental data with building, energy, socioeconomic, demographic, modeling, and/or health impacts data to inform equitable climate and energy solutions. Development of neighborhood-scale visualization/analysis is particularly encouraged.

Applications must clearly indicate what datasets will be integrated, the types of algorithms/approaches to be used, and how the proposed tools are an advance over commercial off the shelf software.

Questions – Contact: Justin Hnilo, Justin.Hnilo@science.doe.gov, Jeff Stehr Jeff.Stehr@science.doe.gov, or Sally McFarlane, Sally.McFarlane@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: Sally McFarlane, Sally.McFarlane@science.doe.gov

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C55-17 COMPLEX DATA: ADVANCED DATA ANALYTIC TECHNOLOGIES FOR SYSTEMS BIOLOGY AND BIOENERGY

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Biological and Environmental Research (BER) program supports transformative science to achieve a predictive understanding of complex biological, earth and environmental systems. BER's Biological Systems Science Division (BSSD) research activities integrate multidisciplinary scientific discovery driven science with technology development to understand plant and microbial systems relevant to national priorities in sustainable energy and innovation in life sciences. BSSD research activities span bioenergy research focused on plant genomics, microbial conversion, sustainable energy, biosystems design (including secure biosystems design), and environmental microbiome research. BSSD's Computational Biology, Biomolecular Characterization and Bioimaging (including quantum enabled bioimaging) activities combined with DOE User Facilities (such as the Joint Genome Institute) serve as key enabling capabilities.

a. Complex Data: Advanced Data Analytic Technologies for Systems Biology and Bioenergy
BSSD science programs generate very large, complex, and multimodal data sets that have all the characteristics of 'big data' – these data sets and associated analytics are critical to BSSD scientific discovery and bio-design applications. Technology improvements in biological instruments from sequencers to advanced imaging devices are continuing to advance at exponential rates, with data volumes in petabytes today and expected to grow to exabytes in the future. These data are highly complex ranging from high throughput "omics" data, experimental and contextual environmental data across multiple scales of observations spanning molecular to cellular to multicellular scale (plants and microbial communities); multiscale 3D and 4D images for conceptualizing and visualizing spatiotemporal expression and function of biomolecules, intracellular structures, and the flux of materials across cellular compartments.

The ability to generate complex multi- "omic" environmental data and associated meta-datasets greatly exceeds the ability to interpret these data. The current need is for general solutions for managing and interpreting complex data and extracting knowledge and information from data sets rather than generating primary data. The objective of analytical and algorithmic approaches could include taxonomy but should also enable integration and functional connection of experimental components. The objective of generalized approaches to data integration should be generation of testable hypotheses and models that propose functional or causal connections among system components.

Innovative solutions and frameworks for management and analysis of large-scale, multimodal, and multiscale data leveraging artificial intelligence and machine learning methods, that enhance effectiveness and efficiency of data processing for investigations across spatial scales and scientific disciplines are needed. These include interoperable computational platforms and data resources to facilitate specialized data workflows starting from data collection, processing, access, sharing, integration, and analysis for large-scale, integrated omics, instrumental, and imaging datasets. Novel approaches, software tools and modelling frameworks for managing, integrating, and analyzing 'big data' will be considered.

Questions – Contact: Ramana Madupu, Ramana.Madupu@Science.doe.gov or Resham Kulkarni, Resham.Kulkarni@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: Ramana Madupu, Ramana.Madupu@Science.doe.gov or Resham Kulkarni, Resham.Kulkarni@science.doe.gov

C55-18 ENABLING TOOLS FOR STRUCTURAL BIOLOGY OF MICROBIAL AND PLANT SYSTEMS RELEVANT TO BIOENERGY

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Biological Systems Science Division (BSSD) supports research to understand, predict, and design biological processes that underpin innovations for bioenergy and bioproduct production and to enhance the understanding of natural environmental processes relevant to DOE. Structural characterization of biological systems and their components provide critical insights that illuminate these processes. Powerful experimental approaches to structural characterization include diffraction, scattering and imaging techniques at the DOE synchrotron and neutron user facilities (which are funded by Basic Energy Sciences; see https://www.energy.gov/science/bes/basic-energy-sciences) as well as cryo-electron microscopy (cryoEM), cryo-electron tomography (cryoET) for molecular or tomographic characterization of biological samples, and micro-electron diffraction (microED). BER supports access, training and user support for experimental capabilities described at www.BERStructuralBioPortal.org to enable experiments for studying and understanding structural and functional processes of importance to the BER Genomic Science program (GSP; see https://genomicscience.energy.gov/index.shtml). These BER-supported capabilities are freely available to all researchers through peer-reviewed facility proposal processes. This SBIR-STTR topic encourages the development of tools necessary for doing experiments at the beamlines or that can facilitate cryoEM/ET or microED investigations.

a. Tools or Instruments for Structural Characterization of Biological Systems Ranging from Atomic to Multi-Cellular Scales

This subtopic solicits the development of robust tools that are needed to improve structural biology and imaging capabilities for researchers studying microbial or plant systems, or their components, relevant to DOE mission interests. For this solicitation, structural biology targets range from the atomic to multi-cellular scale. For this solicitation, technology areas for structural characterization include facility-based x-ray, neutron or infrared beamline-based techniques and cryo-EM/ET or micro-ED for determining the 3D structures of macromolecules, macromolecular complexes, cells, cellular components, or tissues. Examples of concepts responsive to this announcement include tools or instruments for beam focus or alignment, sample preparation, handling, positioning or detection for any of the above mentioned technology areas; tools for correlative approaches will also be considered. This could include detailed evaluation of the same sample with different techniques, or sequential, multi-scalar techniques for macromolecular or multicellular imaging followed by selection of targeted domains for high resolution analysis.

The purpose is to encourage development and commercialization of tools that ease use, improve results, or overcome obstacles associated with existing technologies.

Algorithm development, software or informatics solutions are not included under this subtopic, but could be submitted under the SBIR/STTR Topic C55-17, "Complex Data: Advanced Data Analytic Technologies for Systems Biology and Bioenergy".

Questions – Contact: Amy Swain, Amy.Swain@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: Amy Swain, Amy.Swain@science.doe.gov

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C55-19 BIOIMAGING TECHNOLOGIES FOR BIOLOGICAL SYSTEMS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Bioimaging Science Technology development effort in BER is targeted at creating multifunctional technologies to image, measure, and model organisms, tissues, and key metabolic processes within biological systems of microbial cells and multicellular plant tissues. BER's current focus on developing a scientific basis for plant biomass-based biofuel production requires detailed understanding of the interaction among plant tissues and microbes. In complex communities the identity of cellular and tissue components under different environmental and physical conditions is a necessary first step to prioritize advantageous and deleterious organismal interactions. Further, the ability to track materials and chemical exchanges within and among cells and their environment is crucial to understanding the activity of microbial communities in environmental settings. Grant applications are sought in the following subtopics:

a. Automated Bioimaging Devices for Structural and Functional Characterization of Plant and Microbial Communities

Applications are invited that develop automated stand-alone imaging and measurement microscopes, instrumentation, or analysis software that can identify microbial species, tissue characteristics and chemical exchanges under different environmental and physical conditions. The output should be derived from imaging systems and should generate and manage large complex data sets. Automated system that characterizes multiple metabolic transformations will provide the integrative systems-level data needed to gain a more predictive understanding of complex biological processes relevant to BER.
The instrumentation and devices to be developed for imaging biological systems will have high likelihood to enable an understanding the elements of complex biological systems or ecological niches related to bioenergy or a bioeconomy. The instrumentation would be capable of identifying individual species, tissues, organelles, or biological and structural components in an image and discover the physical conditions, spatial/temporal relationships, physical connections, and chemical exchanges that facilitate the flow of information and materials among organisms or biological components. The primary interest for this solicitation is for innovative bioimaging devices with small footprints, which are fully capable of operation independently of heavy equipment and large instruments (e.g., neutron and light sources, cry electron microscopes, high resolution mass spectrometers), and can be easily deployed in public and private sector to make them accessible to the larger scientific community. Instrumentation could use culture chambers in a laboratory setting with defined biological constructs or could be deployed for field-based evaluation of plants and microbes. The instrumentation should be able to characterize biological systems in controlled physical chemical and environmental conditions for validation and investigate biological systems under experimental conditions that support basic research to understand and optimize biomass-based biofuel production and a bioeconomy.

Instrumentation originally developed for biomedical research could be adapted to investigate biological research supported by BER. However, real, or perceived device developments for medical imaging and/or applications including disease diagnostics or therapies in biological, animal and/or human systems are excluded.

Algorithm development and software that supports instrumentation for the generation of biological images, data and knowledge would be included in this topic. However, general informatics solutions are not included under this subtopic. However, applications for the management and analysis of large-scale, multimodal, and multiscale data leveraging artificial intelligence and machine learning methods could be submitted under the SBIR/STTR Topic C55-17, “Complex Data: Advanced Data Analytic Technologies for Systems Biology and Bioenergy”.

Tools that support facility-based x-ray, neutron or infrared beamline-based techniques and cryo-EM/ET or micro-ED for determining the 3D structures of macromolecules, macromolecular complexes, cells, cellular components, or tissues are not included under this subtopic. However, tools that ease use, improve results, or overcome obstacles associated with existing technologies could be supported under the SBIR/STTR Topic C55-18, Enabling Tools for Structural Biology of Microbial and Plant Systems Relevant to Bioenergy.

Questions – Contact: Paul Sammak, Paul.Sammak@science.doe.gov

b. Quantum Enabled Bioimaging and Sensing Approaches for Bioenergy
Applications are invited that employ innovative, use-inspired technologies that exploit quantum phenomena to surpass limitations of classical optics including resolution and detection limits, signal-to-noise ratio, limitations on temporal dynamics, long term signal stability, sample photodamage and limited penetration, or selective biomolecule sensing. Quantum approaches should propose a comparative advantage over competing classical optical methods. Processes of interest to BER include measuring the chemical and physical environment within individual cells or organelles, enzyme function within cells, tracking metabolic pathways in

vivo, monitoring the transport of materials into and out of cells or across cellular membranes and, measuring signaling processes between cells and within plant-microbe and microbe-microbe interactions.

Current technical limitations and challenges associated with optical imaging and microscopy include: 1) depth imaging - light scattering and diffraction in biological tissue, a major barrier to imaging biological processes deep within tissue (plants or rhizosphere) - restricts optical microscopy to superficial layers, leaving many important biological questions unanswered; 2) photo-damage - classical high flux multiphoton optical imaging causes photo-damage to cellular viability and perturbation to molecular biology for in situ imaging of biological processes in living systems, rendering the sample useless for repeat imaging and measurement of dynamic processes to be performed within the same biological system over different time intervals; and 3) suboptimal stability, brightness and photo-bleaching of the fluorophore when used in combination with an optical imaging approach.

Under this subtopic, applications are sought to explore new quantum science-enabled light sources, imaging detectors or biosensors envisioned to overcome the current challenges of in-depth imaging including associated scattering and diffraction problems, and suboptimal stability and photo-bleaching issues to enable prolonged imaging studies. Quantum entanglement imaging could also be combined with quantum science-based probes for sensing and measurement. These probes can be tailor-made to have high multiphoton cross-sections, multiple chemical functionalities for protein binding and molecular tracking properties, spectrally tunable emission, and quantized absorption/emission states to enable high absorption of multiple entangled photons. Quantum-based biosensors might also detect other physical or chemical cues from the local biological environment and report conditions with photon emissions. Such systems may offer substantial improvement in signal detection and spatial and spectral selectivity by utilizing non-classical properties of light under low excitation power without causing significant photo-damage to cell composition or perturbing the natural biological processes within the cell.

This subtopic seeks fundamental research towards development of new quantum science-enabled probes and sensors applicable for imaging of plant and microbial systems relevant to bioenergy and environmental research conducted within BER programs. These quantum approaches and imaging systems would need to visualize cellular structures and processes in a nondestructive manner, and at sufficient resolution to enable the validation of hypotheses of cellular function occurring in depth. Systems capable of cellular dynamics in vivo would be encouraged but not required. Some research areas of major emphasis within BER include understanding plant metabolism impacting cell wall composition/decomposition, deconstruction of plant polymers (lignin, cellulose, hemicellulose) to monomers, engineered microbial pathways for conversion of plant biomass-derived substrates to fuels and chemicals, and signaling and interactions within environmental microbiomes.

This subtopic encourages the development of new quantum-based imaging approaches and demonstration of their utility for imaging biological systems of relevance to bioenergy and environmental research. Potential applications should address one or more of the topics according to examples outlined below, for prototype development:

- New quantum entanglement-based approaches for probes and sensors, to allow the observation and characterization of multiple complex biological processes occurring in depth within plant and microbial systems nondestructively or in living matter in real-time.
- New quantum entanglement enabled imaging devices with desirable photon intensities and wavelengths to overcome the problems of diffraction and scattering to allow the detection of image signals occurring in depth in a 3D volumetric composition within living plant and microbial systems.

EXCLUSIONS/RESTRICTIONS:

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- Real or perceived developments for medical imaging and/or applications including disease diagnostics or therapies in biological, animal and/or human systems are excluded.
- Standalone development of quantum dots for routine or innovative biological imaging experiments is excluded.
- The use of commercially available quantum dots (QDs), probes, or sensors as standards for data calibration and to study instrument performance for optical imaging experiments as a part of research proposal, are excluded from consideration.

Questions – Contact: Paul Sammak, Paul.Sammak@science.doe.gov

c. Other

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

Questions – Contact: Paul Sammak, Paul.Sammak@science.doe.gov

References: Subtopic a:

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C55-20 BIOLOGICAL APPROACHES AND TECHNOLOGIES FOR SYNTHETIC POLYMER UPCYCLING

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Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Globally, more than 350 million metric tons of plastics or petroleum-based synthetic polymers are produced annually, and their production is anticipated to quadruple by 2050. Approximately 2% of total energy consumption in the United States is used to manufacture plastics, resins, and synthetic rubber and production of major commodity polymers in the U.S. account directly for an estimated 70 million metric tons CO_2 equivalent of greenhouse gases (GHGs). While plastic production consumes nearly 6% of global oil production, plastic consumables are largely only used once and then discarded into landfills and the environment. This suggests that a significant opportunity exists to recover both energy and carbon from plastic waste. DOE therefore seeks to support development of new methods to improve petroleum-based synthetic polymer recycling and upcycling technologies to meet U.S. decarbonization goals.

a. Biological Approaches and Technologies for Synthetic Polymer Upcycling

This topic addresses the need to develop biological solutions for petroleum-based synthetic polymer upcycling that may offer unique advantages over traditional recycling methods. Though petroleum-based synthetic polymers are typically considered to be highly recalcitrant to biological depolymerization, there is evidence that some plastics can be enzymatically deconstructed. Therefore, enzymatic pathways may exist or may be modified to breakdown polymers that currently cannot be recycled. With this topic, BER seeks projects that apply the principles of genome engineering and microbiome science to leverage metabolically engineered organisms and/or within complex communities to deconstruct petroleum-based synthetic polymers and/or to convert polymer waste streams to usable monomers. Projects could apply novel biological mechanisms, enzymes, and pathways for petroleum-based synthetic polymer deconstruction and conversion, and applications should build upon an existing proof of concept.

Applications on the environmental dimension of plastics pollution and/or degradation are not within scope. Primarily descriptive studies that aim only to survey strains, environments, enrichments, or consortia via metagenomic or transcriptomic sequencing are not encouraged. Studies that target human or environmental health aspects of polymers or their breakdown products are not within scope. This topic does not include the development of novel polymers, bioplastics, or biomaterials. Applications should not primarily be focused on the conversion of polymer breakdown products and must be focused on the biological upcycling of petroleum derived synthetic polymers. Early stage, basic research projects are not encouraged.

Applications for research that would result in incremental advances in our current understanding or technology are not encouraged. Experimental studies should be focused on the biological conversion of polymers and synthetic biology. Studies that do not target petroleum-based synthetic polymers as substrates or are solely focused on just the chemical analogs or monomers for petroleum-based synthetic polymer breakdown products are not encouraged.

Questions – Contact: Dawn M. Adin, dawn.adin@science.doe.gov

b. Other

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

Questions – Contact: Dawn M. Adin, dawn.adin@science.doe.gov

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PROGRAM AREA OVERVIEW: OFFICE OF NUCLEAR PHYSICS

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

Nuclear physics research is carried out at national laboratories, international accelerator facilities, and universities. In the US, the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) allows detailed studies of how quarks and gluons bind together to make protons and neutrons. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) is forming new states of matter which have not existed since the first moments after the birth of the Universe. The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) provides stable and radioactive beams directed toward understanding the properties of nuclei at their limits of stability. The Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU) will produce and study highly unstable nuclei that are now formed only in supernovae and neutron star mergers in sufficient numbers, enabling scientists to better understand stellar evolution and the origin of the elements. NP is also supporting the community that is developing technologies necessary for construction of the electron ion collider (EIC) at BNL.

The NP program supports an in-house program of basic research focused on heavy elements at the 88-Inch Cyclotron of the Lawrence Berkeley National Laboratory (LBNL); the operations of accelerators for in-house research programs at two universities (Texas A&M University and the Triangle Universities Nuclear Laboratory (TUNL) at Duke University), which provide unique instrumentation with a special emphasis on the training of students; and non-accelerator experiments, such as large stand-alone detectors and observatories for rare events. Of particular interest is R&D related to future experiments in fundamental symmetries such as neutrinoless double-beta decay experiments and measurement of the electric dipole moment of the neutron, where extremely low background and low count rate particle detections are essential.

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

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

C55-21 NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

Large scale data storage and processing systems are needed to record, store, distribute, and process data from nuclear physics experiments conducted at large facilities in the US, such as Brookhaven National Laboratory's

(BNL) Relativistic Heavy Ion Collider (RHIC), the Thomas Jefferson National Accelerator Facility (TJNAF) Continuous Electron Beam Accelerator (CEBAF), and for the Facility for Rare Isotope Beams (FRIB) at MSU. The electron ion collider (EIC), undergoing design and construction at BNL is anticipated to produce data at rates that will also challenge current computing and storage resources. Experiments at such facilities are extremely complex, involving thousands of detector elements that produce raw experimental data at rates in excess of several tens of GB/sec, resulting in an anticipated annual production of raw data sets of size 50 to 100 Petabytes (PB) at RHIC now, and the EIC in the future. A single experiment can produce reduced data sets of many 100s of Terabytes (TB) which are then distributed to institutions worldwide for analysis, and with the increasing data generation rates at these facilities, multi-PB reduced datasets will soon be common. Increased adoption and implementation of streaming readout protocols will only accelerate the data acquisition rates and the resulting volume of raw data. Besides accelerator-based experiments, next-generation neutrino experiments are also anticipated to produce data at rates and volumes that begin to challenge current computing and storage resource capabilities. Similarly, high-performance computing (HPC) simulations are essential to develop the theory needed to guide and interpret nuclear physics experiments. These "theoretical experiments" can also generate hundreds of TB of raw data, which needs to be analyzed by means of custom software pipelines and archived for future analysis. These simulations include models of nuclear collisions and the astrophysical events that are responsible for the creation of atomic nuclei, as well as calculations of structure of atomic nuclei and nucleons. Specific use examples are in Ref 1.
Research on the management and storage of such large data sets will be required to support these large scale nuclear physics activities.

All applications must explicitly show relevance to the DOE Nuclear Physics (NP) program and must be informed by the state of the art in nuclear physics applications, commercially available products, and emerging technologies. An application based on merely incremental improvements or little innovation will be considered non-responsive unless context is supplied that convincingly shows its potential for significant impact or value to the DOE nuclear physics program.

Applications which are largely duplicative of previously funded research by the Office of Nuclear Physics and/or the Office of Advanced Scientific Computing Research will be considered nonresponsive to this topic. Applicants are strongly encouraged to review recent SBIR/STTR awards from the Office of Nuclear Physics. Those awards can be found at https://science.osti.gov/sbir/Awards (Release 1, DOE Funding Program: Nuclear Physics or Advanced Scientific Computing Research).

The subtopics below refer to innovations that will advance our nation's capability to perform nuclear physics research, and more specifically to improve DOE NP Facilities and the wider NP community's programs. Although applicants may wish to gather information from and collaborate with experts at DOE National Laboratories to establish feasibility for their innovations, DOE expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry. Applications using the resources of a third party (such as a DOE laboratory) must include in the application, a letter of certification from an authorized official of that organization.

Please note: following award, all DOE SBIR/STTR grant projects requiring high performance computing support are eligible to apply to use the DOE National Energy Research Scientific Computing Center (NERSC) resources. NERSC is the primary scientific computing facility for the DOE. If you think you will need to use the computing capabilities of NERSC during your Phase I or Phase II project, you may be eligible for this free resource. Learn more about NERSC and how to apply for NERSC resources following the award of a Phase I or Phase II project at http://www.nersc.gov/users/accounts/allocations/request-form/.

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Applications are sought only in the following subtopics:

a. Tools for Large Scale, Widely Distributed Nuclear Physics Data Processing

A trend in nuclear physics is to maximize the use of distributed storage and computing resources by constructing end-to-end data handling and distribution systems, with the aim of achieving fast data processing and/or increased data accessibility across many disparate computing facilities. Such facilities include local computing resources, university-based clusters, major DOE funded computing resources, and commercial cloud offerings.

Applications are sought for:

1. Software techniques to improve the effectiveness of storing, retrieving, and moving such large volumes of data (> 1 PB/day), possibly including but not limited to automated data replication, data transfers from multiple sources, or network bandwidth scheduling to achieve the lowest wait-time or fastest data processing;
2. Effective new approaches to data mining or data analysis through data discovery or restructuring. Examples of such approaches might include fast information retrieval through advanced metadata searches or in-situ data reduction and repacking for remote analysis and data access;

Open-source software solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and declined without review.

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate for Software and Data Management: Gulshan Rai, Gulshan.Rai@science.doe.gov.

b. Applications of AI/ML to Nuclear Physics

As discussed above, analysis of experimental, theoretical, and simulation data is a central task in the NP community. In the case of medium scale experiments, data sets will be collected with each event having a large number of independent parameters or attributes. The manipulation of these complex datasets into summaries suitable for the extraction of physics parameters and model comparison is a difficult and time-consuming task. Currently, both the national laboratory and university-based groups carrying out experimental and simulation analyses maintain local computing clusters running domain specific software, often written by nuclear physicists. Likewise, theoretical groups, after generating data on a multitude of HPC platforms, perform analysis on the HPC resources and analysis machines at computing facility and on local clusters. Concurrently, the data science community has developed tools and techniques to apply machine learning (ML) and artificial intelligence (AI) for pattern finding and classification in large datasets, promising new avenues for analyses of this kind. These tools are generally open-source and can be effectively deployed on platforms ranging from distributed computing resources provided by commercial cloud services to leadership computing facilities. Application of these new ML and AI technologies to the analysis of nuclear physics data requires the development of domain specific tools. Such tools include the application of specific AI algorithms and techniques for the preparation and staging of large training sets. Sources of such data are described in Topic C55-24 (Nuclear Instrumentation, Detection Systems and Techniques).

Applications are sought to develop:

1. ML and AI technologies to address a specific application domain in experimental, simulation, and/or theoretical nuclear physics data analysis. Applications should address performance and plan to

demonstrate feasibility to non-experts in computer systems with working prototypes and comprehensive tutorials and/or documentation.
2. ML and AI technologies implemented within high-performance computing simulations to encapsulate essential physics to increase the fidelity of simulations and/or reduce the time to solution.

Applicants are strongly encouraged to consult the references and open literature to best understand the tools already in use by the community. Open-source software solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and declined without review.

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c. Heterogeneous Concurrent Computing

Computationally demanding theory calculations as well as detector simulations and data analysis tasks are significantly accelerated through the use of general-purpose Graphics Processing Units (GPUs). The use of Field Programmable Gate Arrays (FPGAs) based computing is also being explored by the community. The ability to exploit these hardware solutions for concurrent computing has been significantly constrained by the effort required to port the software to these computing environments.

Applications are sought to develop:

1. Cross compilation or source-to-source translation tools that are able to convert conventional as well as very complicated templatized code into high performance implementations for heterogeneous architectures.

Utilizing High Performance Computing (HPC) and Leadership Computing Facilities (LCFs) is of growing relevance and importance to experimental NP as well. Most HPC and LCF facilities are evolving toward hybrid CPU and GPU architectures oriented towards machine learning. Existing analysis codes do not sufficiently reveal the concurrency necessary to exploit the high performance of the architectures in these systems. NP analysis problems do have the potential data concurrency needed to perform well on multi- and many-core architectures, but currently struggle to achieve high efficiency in both thread-scaling and in vector utilization. NP experimental groups are increasingly invited and encouraged to use such facilities, and DOE is assessing the needs of computationally demanding experimental activities such as data analysis, detector simulation, and error estimation in projecting their future computing requirements.

Applications are sought to develop:

1. tools and technologies that can facilitate efficient use of large-scale CPU-GPU hybrid systems for the data-intensive workflows characteristic of experimental NP. Such tools can provide capability to utilize the heterogeneous LCF architectures and/or they can mask the embarrassingly parallel nature of the analysis needs and support the simultaneously scheduling of GPU-intense and CPU-only workflows on the same nodes with sophisticated workflow management tools. Ideally, tools should be designed, and interfaces constructed, in such a way to abstract low-level computational performance details away from users who are not computer scientists, while providing users who wish to perform optimizations effective and expressive application programming interfaces to accomplish this.

Open-source software solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of

Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and declined without review.

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate for Software and Data Management: Gulshan Rai, Gulshan.Rai@science.doe.gov.

d. Other

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

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate for Software and Data Management Gulshan Rai, Gulshan.Rai@science.doe.gov.

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C55-22 NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The DOE Office of Nuclear Physics (NP) seeks new developments in detector electronics with significantly improved energy, position, timing resolution, sensitivity, rate capability, stability, dynamic range, and background suppression. Of particular interest are innovative readout electronics for use with the nuclear physics detectors described in Topic C55-24 (Nuclear Instrumentation, Detection Systems and Techniques). An important criterion is the cost per channel of electronic devices and modules.

Nuclear physics detectors range in complexity, from those that fill a modest-sized laboratory to those that fill a multistory building. While most detectors may operate at or near room temperature, those used in rare decay experiments like neutrinoless double beta decay operate at cryogenic temperatures, below 20 mK for some

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experiments. This underscores that, in general, nuclear physics electronics operate in extreme environments, whether at extreme cryogenic temperatures or where radiation levels are high.

All applications must explicitly show relevance to the NP program. Applications must be informed by the state of the art in nuclear physics applications, commercially available products and emerging technologies. An application based on incremental improvements or little innovation will be considered non-responsive unless context is supplied that convincingly shows its potential for significant impact or value to the DOE nuclear physics program.

Applications which are largely duplicative of previously funded research by the NP will be considered nonresponsive to this topic. Applicants are strongly encouraged to review recent SBIR/STTR awards from the NP to avoid duplication. Those awards can be found at https://science.osti.gov/sbir/awards/ (Release 1, DOE Funding Program: Nuclear Physics).

The subtopics below refer to innovations that will advance our nation's capability to perform nuclear physics research, and more specifically to improve scientific productivity at NP facilities and the wider NP community's programs. Applicants may wish to gather information from and collaborate with experts at DOE National Laboratories to establish feasibility for their innovations. DOE expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry. Applications that propose using the resources of a third party (such as a DOE laboratory) must include in the application, a letter of certification from an authorized official of that organization.

Applications are sought only in the following subtopics:

a. Advances in Digital Processing Electronics

Digital signal processing electronics are needed, following low noise amplification and anti-aliasing filtering, in nuclear physics applications.

Applications are sought to:

1. develop high speed digital processing electronics that, relative to current state of the art, improve the effective number of bits to 16 at sampling rates of > 4GHz and a bandwidth > 2 GHz, with minimal integral non-linearity, and minimal, or at least repeatable differential non-linearity. Such devices should have 64 channels with fast timing (< 10 ps). If deployed where radiation levels are high, then they must be rad-hard (tolerate 10 Mrad with 10^{15} n/cm^2).
2. Develop high channel density (>=256 channels/board) digital data acquisition system with >= 100 MSPS, >=12 bit ADC information per channel

Emphasis should be on low power dissipation and low cost per channel.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate(s) for Electronics and Circuits: Manouchehr Farkhondeh, Manouchehr.Farkhondeh@science.doe.gov.

b. Front-End Application-Specific Integrated Circuits

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Applications are sought to develop front-end application-specific integrated circuits (ASICs) for amplifying and processing data from highly-segmented solid-state and gas detectors in pixels, strips or drift configurations, including silicon photomultipliers (SiPM), multi-channel plate photomultipliers (MCP-PMTs), large area picosecond photodetectors (LAPPD) and germanium detectors.

Microelectronics of specific interest include:

1. (1) Very low power, and/or very low noise charge amplifiers and filters, very high rate photon-counting circuits, high-precision charge and timing measurement circuits, low-power and small-area ADCs and TDCs, efficient sparsifying and multiplexing circuits. Native control and readout using fiber w/WDM so multiple ASICs can be serviced by one fiber is desired. The proposed hardware must clearly advance in the state-of-the-art;
2. (2) Two-dimensional high-channel-count circuits for small pixels combined with high-density, high-yield, and low-capacitance interconnection techniques. Layering these 2D ASICS via interconnects to increase functionality is also of interest;
3. (3) Microelectronics for extreme environments such as high-radiation (both neutron and ionizing) and low temperature, depending on the application. Specifications for the former are: high channel count (64 channels) ASIC with fast timing (< 10 ps), high radiation hardness (10 Mrad with 10^{15} n/cm^2), fast waveform sampling (> 4GHz) and bandwidth (> 2GHz); and
4. (4) Very-large-scale systems-on-chip or experiments-on-chip characterized by high functionality, high programmability, DSP capabilities, high data rate interface.

Relative to the state of the art these circuits should be low-cost, user friendly, and capable of communicating with commercial auxiliary electronics.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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c. Next Generation Pixel Sensors

The Electron-Ion Collider (EIC) plans to operate at luminosities in the range 10^{33}–10^{34} cm^{-2} s^{-1} and will require radiation hard tracking devices placed at radii less than 10 cm from the beam axis. Upgrades to detectors at other NP facilities would benefit as well. Therefore, alternatives to the present generation high density Active Pixel Sensors will be required.

Applications are also sought for:

1. the next generation of active pixel sensors. Options may include integrated CMOS detectors which combine initial signal processing and data sparsification on a high-resistivity silicon, superconducting large area pixel detectors, and novel 2.5D- and 3D-pixel materials and geometric structures.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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d. Other

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

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate(s) for Electronics and Circuits: Manouchehr Farkhondeh, Manouchehr.Farkhondeh@science.doe.gov.

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C55-23 NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Nuclear Physics (NP) Program supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy ion, electron, and proton accelerators and their associated systems. Research and development (R&D) is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the enabling technologies of the Brookhaven National Laboratory's (BNL) Relativistic Heavy Ion Collider (RHIC), the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF), the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory, and the

Facility for Rare Isotope Beams (FRIB) at Michigan State University. Also of interest are technologies relevant to the development of the Electron-Ion Collider (EIC) to be constructed at BNL. All of the above facilities make use of superconducting technologies, including superconducting radio frequency (SRF) accelerator components, superconducting magnets, and supporting infrastructure and technologies. Relevance to nuclear physics must be explicitly described, as discussed in more detail below.

All applications must explicitly show relevance to the DOE NP Program. Applications must be informed by the state of the art in nuclear physics applications, commercially available products, and emerging technologies. An application based on merely incremental improvements or little innovation will be considered non-responsive unless context is supplied that convincingly shows its potential for significant impact or value to the DOE NP Program.

Applications which are largely duplicative of previously funded research by NP or the Office of High Energy Physics will be considered nonresponsive to this topic. Applicants are strongly encouraged to review recent SBIR/STTR awards from NP to avoid duplication. Those awards can be found at https://science.osti.gov/sbir/awards/ (Release 1, DOE Funding Program: Nuclear Physics).

The subtopics below refer to innovations that will advance our nation's capability to perform nuclear physics research, and more specifically to improve existing or planned DOE NP Scientific User Facilities and the wider NP community's experimental programs. Although applicants may wish to gather information from and collaborate with experts at DOE National Laboratories, for example, to establish feasibility for their innovations, DOE expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry. Applications using the resources of a third party (such as a DOE laboratory) must include in the application a letter of certification from an authorized official of that organization.

Please note: following award, all DOE SBIR/STTR grant projects requiring high performance computing (HPC) support are eligible to apply to use the DOE National Energy Research Scientific Computing Center (NERSC) resources. NERSC is the primary scientific computing facility for the DOE. If you think you will need to use the HPC capabilities of NERSC during your Phase I or Phase II project, you may be eligible for this free resource. Learn more about NERSC and how to apply for NERSC resources following the award of a Phase I or Phase II project at http://www.nersc.gov/users/accounts/allocations/request-form/.

Applications are sought only in the following subtopics:

a. Materials and Components for Radio Frequency Devices

Applications are sought to improve or advance superconducting and normal-conducting materials or components for RF devices used in particle accelerators.

Areas of interest include;

1. peripheral components for both room temperature and superconducting structures, such as beam pipe absorbers, particulate-free bellows, NEG pumps, and RF-shielded gate valves and associated low-loss cryogenic beam line flange connections. Design should be for a common flange size, e.g., 2.75", with scalability to larger sizes;
2. techniques for removal of 1 μm and larger particulates in diameter from the inner surfaces of superconducting cavities to replace or compliment high-pressure water rinsing e.g., methods for cleaning whole cryomodules, alternative techniques to dry ice and high-pressure water cleaning; and

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3. metal forming techniques, with the potential for significant cost reductions by simplifying elliptical cavity sub-assemblies, e.g., dumbbells and end groups, as well as eliminating or reducing the number of electron beam welds.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov

b. Design and Operation of Radio Frequency Beam Acceleration Systems

Applications are sought for the design, fabrication, and operation of radio frequency accelerating structures and systems for electrons, protons, as well as light- and heavy-ion particle accelerators as enumerated.

1. innovative techniques for relative field control and synchronization of multiple crab structures (0.01° of phase and 0.01% amplitude RMS jitter) in the presence of 10-100 Hz microphonics-induced variations of the structures' resonant frequencies (0.1-1.5 GHz); and
2. a high gain (for example, with quality factor at a few hundred) & low delay (a few hundred nano-second) RF control system for SRF crab cavities
3. development of wide tuning (with respect to the center frequency of up to 10^{-4}) SRF cavities for acceleration and/or storage of relativistic heavy ions;

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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c. Particle Beam Sources and Techniques

Applications are sought to develop:

1. methods and/or devices for improving emission capabilities of photocathode sources (polarized and unpolarized) used by the nuclear physics community, such as improving charge lifetime, bunch charge, average current, emission current density, emittance, or energy spread (Note, Letters of Intent or applications proposing the use of diamond amplifiers and variants will be considered nonresponsive.);
2. novel technologies for ion sources capable of generating high-intensity, high-brightness, high charge state heavy ion beams, for example: ~12 pμA of uranium beam at charge states between q=32 and 46 with rms emittance of 0.1π mm-mrad. If an oven is used to provide uranium beams with these properties, the high temperature oven must reliably reach 2300 °C within the high field of the electron-cyclotron resonance (ECR) ion source injection region;
3. novel quench protection systems for Nb_3Sn and high-temperature superconducting (HTS) 4th and 5th Generation ECR ion source combined function magnets (sextupole and solenoids);
4. efficient continuous wave (cw) positron beam sources (polarized and unpolarized) motivated by the nuclear physics community, aimed at improving aspects of pair-production targets, operating at low energy (10-200 MeV), high power (50-100 kW), and at several 100 MHz; and
5. high average current (>20 mA) and high voltage (>200 kV) reliable and stable power supplies for high current electron beam sources for beam cooling and positron production

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Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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d. Polarized Beam Sources and Polarimeters

With respect to polarized sources, applications are sought to develop:

1. Associated components for significantly improving performance of high current CW polarized electron sources for delivering beams of ~1-10 mA, with longitudinal polarization greater than 90%; and a photocathode quantum efficiency > 5% at ~780 nm.
2. absolute polarimeters for spin polarized ^{3}He beams with energies up to 160 GeV/nucleon;
3. polarimeter concepts for bunch by bunch hadron polarimetry with a bunch spacing as short as 2 ns;
4. advanced electron or positron beam polarimeters such as those that operate in the energy range of 1-100 MeV, with average currents exceeding 100 uA, with accuracies that are <1%;
5. steering and/or lens magnets for helicity correlated beam corrections, providing rectangular waveforms with rise time <10 microseconds; and,
6. low energy <10 MeV electron spin rotators providing < +/- 5 deg precession, with minimum disturbance to beam properties

For applications involving software, open-source solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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e. Rare Isotope Beam Production Technology

Applications are sought to develop:

1. Radiation resistant stepper motor with radiation tolerance to 10^4 Gy (10^6 rad);
2. Development of a non-destructive diagnostics system to measure intensities of fast (~100-200 MeV/u) rare isotope beams in the range from 10^4 to 10^{11} ions/sec;
3. Development of radiation hard tracking detector system for phase space diagnostics of ions. If possible, it should avoid the need for gases. Ideal conditions as follows: particle rates up to ~10^4 Hz, 30 cm by 20 cm detection region; ~1mm position resolution for ions with Z>10 [21];
4. Development of additive manufacturing technologies (3D printing) for construction of superconducting coils for Walstrom type [24] large aperture multipoles for fast rare isotope beam spectrometers; and
5. Development of alternative manufacture technologies (for example, hydroforming) for high power (up to 300 kW) beam dump for ~ 200 MeV/u heavy ion beam
6. Compact digital imaging systems are sought for beam and target system diagnostic applications. Sensor should be capable of HD image resolution, and demonstrate usable sensitivity from 440 nm to >1000 nm. Sensors and electronics should be functional through integrated doses of >1 MRad, with functionality up to 100 MRad preferred. Signal and power over Ethernet (PoE) is desirable.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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f. Accelerator Control and Diagnostics

As accelerator facilities advance in their capabilities, it is important that diagnostics and controls keep pace. Applications are sought to develop advanced beam diagnostics for concepts and devices that provide high speed measurements, real-time monitoring, and readout of particle beam intensity, position, emittance, polarization, luminosity, transverse profile, longitudinal phase space, time of arrival, and energy. More specifically:

For facilities that produce high average power beams, applications are sought for

1. measurement devices/systems for cw beam currents in the range 0.01 to 100 µA, with very high precision ($<10^{-4}$) and short integration times;
2. non-intercepting beam diagnostics for stored proton/ion beams, and/or for ampere class electron beams; and
3. devices/systems that measure the emittance of intense (>100 kW) CW ion beams

For heavy ion linear accelerator beam facilities, applications are sought for

1. beam diagnostics for ion beams with intensities less than 10^7 nuclei/second over a broad energy range up to 400 MeV/u (an especially challenging region is for intensities of 10^2 to 10^5 with beam energy from 25 keV to 1 MeV/nucleon);
2. diagnostics for time-dependent, multicomponent, interleaved heavy ion beams. The diagnostic system must separate time-dependent constituents (total period for switching between beams >10 ms), where one species is weaker than the other, and is ~5% of a 30 - 100 ms cycle. The more intense beam would account for the remainder. Proposed solutions which work over a subset of the total energy range are acceptable;
3. on-line, minimally interceptive systems for measurement of beam contaminant species or components. (Energy range of primary ion species should be 500 keV/nucleon to 2 MeV/nucleon.); and
4. advanced diagnostic methods and devices for fast detection (e.g. < 10 us) of stray beam loss for low energy heavy ion beams (e.g. ions heavier than argon at energies above 1 MeV/nucleon and below 100 MeV/nucleon) to facilitate accelerator machine protection.
5. High-sensitivity non-intercepting BPMs for heavy ion Re-Accelerators for ion beamlines that transport pulse-averaged currents >1 epA up to 100 enA. Systems should demonstrate spatial resolution <1 mm in both horizontal and vertical planes over apertures >50 mm diameter, and provide phase measurement for highly bunched beams in the 20-100 MHz range with resolution <1-degree; and
6. Digital Data Acquisition Control Systems Integration: High rate digital DAQ and nuclear electronics signal processing systems are sought for integration with particle identification detector networks in high flux beamlines. Systems should be integrable with SCADA controls systems (eg. EPICS) and provide control surfaces for digitally implemented components such as constant fraction discriminators, scalers, and multi-channel analyzers. Single channel processing and readout rates should exceed 1e5 pps.

For accelerator controls, applications are sought to develop:

1. A Webkit application framework to enable the development of data visualization and controls tools; and
2. software applications for collection, visualization, and analysis of post-mortem data from beam line data acquisition and storage devices.

Applications to this subtopic should indicate familiarity with complex accelerator systems and the interfaces between the beamline diagnostics and the control systems in use at large accelerator installations. That could also include smaller accelerators like those at Texas A&M's Cyclotron Institute, TUNL at Duke University, and tandem accelerator facilities supported by the National Science Foundation at universities like Notre Dame and Ohio University.

For applications involving software, open-source solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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g. Magnet Development for NP facilities

A full utilization of the discovery potential of the EIC will require a full-acceptance detector system that can provide detection of reaction products scattered at small angles with respect to the incident beams over a wide momentum range. In general, NP's other high beam power facilities have similar needs for their beamline magnets. Applications are sought for hardware developments to reduce the production costs of these magnets and to the supporting subsystems.

1. cost-effective materials and manufacturing techniques for interaction region or other beamline magnets, including components for an integrated cold magnet assembly such as support systems, compact cold to warm transitions, and cold BPMs; and
2. high efficiency cooling methods and cryogenic systems; and more efficient, lower cost power supplies for such magnets.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics accelerator facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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h. Other

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

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C55-24 NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Applications: YES	Accepting STTR Applications: YES

The Office of Nuclear Physics (NP) supports grants that will lead to advances in detection systems, instrumentation, and techniques for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art needed at universities, national scientific user facilities, and facilities worldwide. Next-generation detectors are needed for the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF), the Facility for Rare Isotope Beams (FRIB) at Michigan State University, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab (BNL), the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory, and the Electron-Ion Collider (EIC) under development at BNL. Also of interest is technology related to future experiments in fundamental symmetries, such as neutrinoless double-beta decay (NLDBD). In the case of NLDBD experiments, extremely low background and low count rate in particle detection are essential.

All applications must explicitly show relevance to the DOE NP Program. Applications must be informed by the state of the art in nuclear physics applications, commercially available products and emerging technologies. An application based on merely incremental improvements or little innovation will be considered non-responsive unless context is supplied that convincingly shows its potential for significant impact or value to the DOE NP Program.

Applications which are largely duplicative of previously funded research by NP will be considered nonresponsive to this topic. Applicants are strongly encouraged to review recent SBIR/STTR awards from NP to avoid duplication. Those awards can be found at https://science.osti.gov/sbir/Awards (Release 1, DOE Funding Program: Nuclear Physics).

The subtopics below refer to innovations that will advance our nation's capability to perform nuclear physics research, and more specifically to improve scientific productivity at DOE NP facilities and the wider nuclear physics community's programs. Applicants may wish to gather information from and collaborate with experts at DOE National Laboratories to establish feasibility for their innovations. DOE expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry. Applications that propose using the resources of a third party (such as a DOE laboratory) must include in the application, a letter of certification from an authorized official of that organization.

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resource. Learn more about NERSC and how to apply for NERSC resources following the award of a Phase I or Phase II project at http://www.nersc.gov/users/accounts/allocations/request-form/.

Grant applications are sought in the following subtopics:

a. Advances in Detector and Spectrometer Technology

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

Particle identification and counting detectors such as:

1. Large area Multigap Resistive Plate Chamber (MRPC) detectors with very high rate capability (≥200 kHz/cm^2) radiation (10 Mrad with 10^{15} n/cm^2), magnetic field tolerance (2-3 T), and high timing resolution≤ 10 ps for time-of-flight detectors. The accompanying readout system (i.e., electronics, application-specific integrated circuit, etc.) should be compatible with the above requirements as well; and
2. Cherenkov detectors (Threshold, Ring-Imaging (RICH), Detection of Internally Reflected Cherenkov Light (DIRC)) with broad particle identification capabilities over a large momentum range and/or large area that can operate at a high rate in noisy (very high rate, low-energy background) environments and that are also magnetic field tolerant;

For applications involving software, open-source solutions are strongly encouraged. Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

Questions – Contact: Michelle Shinn, Michelle.Shinn@science.doe.gov or the NP SBIR/STTR Topic Associate for Instrumentation, Detection Systems and Technique: Elizabeth Bartosz, Elizabeth.Bartosz@science.doe.gov

b. Development of Novel Gas and Solid-State Detectors

Nuclear physics research has the need for devices to track charged and neutral particles such as neutrons and photons. Items of interests are detectors with very good energy resolution for low- and medium-energy applications, high precision tracking of different types of particles, with fast triggering capabilities, as well as detectors that provide high energy and position resolution at high count rates (e.g. > 1 Mcps).

Grant applications are sought to develop detector systems with focus on:

1. Next generation, heavy ion focal plane detectors or integrated detector systems for magnetic spectrometers and recoil separators with high time resolution (< 150ps FWHM), high energy loss resolution (<1%), and high total energy resolution (<1%), and high position resolution (<0.4 mm FWHM);
2. Novel detector concepts such as Micropattern Gas Detectors (GEMs, Micromegas, MicroRWELLs, etc) and Parallel Plate Avalanche Chambers, for charged particle tracking, capable of submillimeter position resolution (less than a few hundred micrometers), using novel readout plane geometries offering low channel counts, high counting rate capability (> 1 MHz and/or (>200 kHz/cm^2), uniform energy-losses independent of the position, high dynamic range and low thickness (< a few mg/cm^2);
3. High-rate, high-radiation hard, precision tracking devices capable of detecting low-energy reaction products such as those from few-GeV Compton and Moller scattering; and

4. Cost effective readout for the above with high-speed data buffering compatible with trigger decisions up to 1 μsec later and fast data ports to allow second level triggers. "Dead time-less data acquisition" when incorporated as a tracker for beam identification and beam particle phase space determination.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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c. Technology for Rare Decay and Rare Particle Detection

Applications are sought for detectors and techniques to measure very weak or rare event signals. Such detector technologies and analysis techniques are required in searches for rare events such as NLDBD or for new isotopes produced far from stability at rare isotope beam and high intensity stable beam facilities. Rare decay and rare event detectors require large quantities of ultra-clean materials for shielding and targets. Future detectors require unprecedented sensitivity and accuracy and could benefit from the use of quantum information sensors and adjacent supporting technologies. The adoption of these sensors in NP applications depends on the development of fabrication techniques at scale to increase availability at lower cost.

Applications are sought to develop:

1. Detectors based on uniquely quantum properties such as superposition, entanglement, and squeezing;
2. Detectors with very high resolution (tenths of micrometers spatial resolution and tenths of eV energy resolution). Bolometers, including the required thermistors, based on cryogenic semiconductor materials, transition edge sensors, Superconducting Tunnel Junction (STJ) radiation detectors, or other new materials are eligible;
3. Novel methods capable of discriminating between interactions of gamma rays and charged particles in rare event experiments;
4. Methods by which the background interactions in rare event searches, such as those induced by gamma rays or neutrons, can be tagged, reduced, or removed entirely; and
5. Non-intercepting event-by-event ion detection of a relativistic beam of heavy ions for particle identification.

Applications must clearly indicate how Phase I research and development will result in a working prototype or method that will be completed by the end of Phase II. The prototype or method must be suitable for testing in a nuclear physics application and/or at a nuclear physics facility. Applications not meeting this requirement will be considered nonresponsive and will not undergo merit review.

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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

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