U.S. Department of Energy

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

Topics

FY 2025
Phase I
Release 1

Version 2, July 12, 2024

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

Schedule

Event	Dates
Topics Released:	Monday, July 8, 2024
Funding Opportunity Announcement Issued:	Monday, August 5, 2024
Letter of Intent Due Date:	Tuesday, August 27, 2024, 5:00pm ET
Application Due Date:	Tuesday, October 8, 2024, 11:59pm ET
Award Notification Date:	Monday, January 6, 2025*
Start of Grant Budget Period:	Tuesday, February 18, 2025

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	July 8, 2024	Original
Ver. 2	July 12, 2024	• Letter of Intent Due Date Correction

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INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2025 DOE SBIR/STTR Phase I Release 1 Funding Opportunity Announcement scheduled to be issued on Monday, August 5, 2024. 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://pamsexternalhelp.science.energy.gov/pages/viewpage.action?pageId=103186436. Please check out the tutorials--a series of short videos designed to get you up to speed quickly.

PARTNERING RESOURCES

The Office of SBIR/STTR Programs has released its SBIR Partnering Platform that helps applicants and awardees (***INNOVATORS***) identify and engage with the myriad of partners (***PARTNERS***) required throughout technology development and productization. Partners registered on the platform include industry stakeholders, investors, national labs, academia, and related ecosystems and include subject matter experts (SMEs), collaborators, subcontractors, manufacturers, engineering/prototype designers, test/certification resources as well as technical and business assistance (TABA) business service providers (accounting, market research, strategy, grant writing, marketing materials, web design), etc. The platform offers key word searching as well as AI to find and identify funding opportunities as well as partners, confidential messaging between parties and bookmarking of identified favorites.

Looking to engage with the National Laboratories to find SMEs, subcontractors, collaborators or even patented technologies to license for commercial development? Visit https://labpartnering.org/labs to search opportunities at each laboratory.

The American-Made Network is an excellent resource for finding commercialization-assistance providers and vendors with specific expertise across DOE's Office of Energy Efficiency and Renewable Energy's (EERE's) technology sectors. The Network helps accelerate innovations through a diverse and powerful group of entities that includes National Laboratories, energy incubators, investors, prototyping and testing facilities, and other industry partners from across the United States who engage, connect, mentor, and amplify the efforts of small businesses. The Network can help companies solve pressing technology challenges, forge connections, and advance potentially game-changing ideas and innovations.

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 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.

Publicly available market research studies. As part of our Phase 0 Application Assistance Program, the DOE Program Offices participating in SBIR/STTR have commissioned various market research studies related to SBIR/STTR topic areas. Many of these reports are publicly available on our website to facilitate commercialization planning for SBIR/STTR applicants and awardees.

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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 control complex phenomena important to the Department of Energy. A particular goal of this program is fulfilling the scientific potential of computing systems, tools, and techniques that require significant modifications to deliver on the promise of exascale science. ASCR funds research at public and private institutions and at DOE laboratories with the purpose of fostering and supporting fundamental progress in applied mathematics, computer science, and high-performance networks. In addition, ASCR supports multidisciplinary science activities under the Computational Partnerships program 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) [1] at Oak Ridge National Laboratory (ORNL), the Argonne Leadership Computing Facility (ALCF) [2] at Argonne National Laboratory (ANL), and the National Energy Research Scientific Computing Center (NERSC) [3] at Lawrence Berkeley National Laboratory (LBNL).

Examples of areas supported by ASCR:

a) Applied and computational mathematics to develop the algorithms, tools, and libraries needed to model complex physical and biological systems;
b) HPC science to develop scalable software and programming models that facilitate the effective utilization of exascale computers for the DOE mission;
c) Critical and emerging computing technologies such as quantum computing and artificial intelligence;
d) Distributed network environments to develop software tools and network services to enable large-scale scientific collaboration and that make effective use of distributed computing and science facilities in support of the DOE science mission;
e) Applied computational partnership to achieve scientific breakthroughs via computer simulation technologies that are impossible without interdisciplinary efforts.

For additional information regarding ASCR priorities, click here.

Please note that all DOE SBIR/STTR grant projects requiring high performance computing support are eligible to apply to use DOE National Energy Research Scientific Computing Center (NERSC) resources [3]. 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 desiring access to any of DOE's Open Science Computing facilities (OLCF [1], ALCF [2], and NERSC [3]) may submit an application to the facility's Director's Discretionary allocation program. Applicants who already have used the DOE facilities, may consider applying for the ASCR Leadership Computing Challenge (ALCC) program [4]. ALCF has a website that includes the information 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. 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.

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

Overview 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 21, 2024) 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 21, 2024) 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 21, 2024) 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 21, 2024)

C59-01. ACCELERATING THE DEPLOYMENT OF ADVANCED SOFTWARE TECHNOLOGIES

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

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- **Artificial Intelligence:** DeepHyper (https://deephyper.github.io/), LBANN (https://github.com/LLNL/lbann)
- **Software for Quantum Computing and Information:** Proposed products stemming from ASCR-funded software and algorithms for quantum information science are in-scope. See https://science.osti.gov/ascr/Research/Quantum-Information-Science-QIS.

Note that software packages that have received ASCR funding as part of SciDAC and other computational partnerships are eligible. Please 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. Risks that are lowered by contributions from a diverse community of stakeholders include, but are not limited to, risks associated with a lack of timely correction of software defects. 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).

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 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, web interfaces, or interfaces for alternative programming languages (e.g., 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 that are 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: David Rabson, david.rabson@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: David Rabson, david.rabson@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: David Rabson, david.rabson@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 21, 2024))
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 21, 2024)
3. Heroux, M. A., Carter, J., Thakur, R., Vetter, J. S., et al, 2020, 2020, ECP Software Technology Capability Assessment Report-Public, ECP-RPT-ST-0002-2020-Public, ECP, https://www.exascaleproject.org/wp-content/uploads/2020/02/ECP-ST-CAR-V20-1.pdf (June 21, 2024)
4. U.S. Department of Energy, 2022, Exascale Computing Project, https://www.exascaleproject.org/ (June 21, 2024)

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 21, 2024)
6. Market Research Study: *Applications of ASCR HPC Software*, 2022, https://science.osti.gov/ascr/Community-Resources/Program-Documents (June 21, 2024)

C59-02. HPC CYBERSECURITY

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

The Office of Science (SC) provides world-class research infrastructure to accelerate scientific discovery within the DOE mission space. DOE SC ASCR user facilities include a high-performance network (HPN) and three HPC systems dedicated to open science research.

Each user facility is uniquely designed for the science it serves. For instance, HPC systems offer a massively parallel computing environment with numerous distributed nodes—login, compute, and data transfer nodes; high-speed interconnects; thousands of heterogeneous advanced processers such as CPUs and GPUs; and sophisticated schedulers, highly distributed file systems, and data storage systems. Scientific research infrastructure requires tailored cybersecurity approaches that accommodate specialized computational platforms and networks and respect an open science paradigm.

HPC platforms are different from enterprise systems in ways that require tailored cybersecurity solutions. Operating system level tools traditionally used for enterprise systems may be inapplicable to distributed operating systems. The balance between performance and cybersecurity, as well as cybersecurity benchmarking, may be more challenging on HPC systems that are designed to deliver unprecedented performance. In addition, HPC software infrastructures evolve more rapidly than commercial counterparts while at the same time some HPC practitioners are actively investigating deployment of approaches more common in conventional server environments, such as, but not limited to, container software architectures.

This topic area seeks applications that are tailored specifically to the unique needs of HPC systems. The narrative must convey a clear understanding of how HPC system architectures differ from enterprise platforms and consequently require tailored cybersecurity solutions, and how the applicant's proposed solution meets these unique needs. For instance, but not limited to, the narrative must describe the applicant's plan to ensure that the proposed HPC cybersecurity tool or technology does not impede HPC performance.

In order to be considered in scope, grant applications for this topic area must clearly propose a cybersecurity solution that specifically reduces the cyberattack surface of HPC systems or component technology unique to HPC platforms. Component technologies unique to HPC platforms are not used in enterprise platforms.

The narrative must clearly articulate how the proposed cybersecurity solution will not impede HPC performance.

Subtopics:

a. Strengthening Isolation Between HPC Users

This topic's goal is to strengthen the isolation between HPC users, specifically in the context of either the HPC scheduler or the HPC filesystem. Developing a tool or technology that, for instance but not limited to, ensures

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an HPC node allocated to an authenticated user can only mount parts of the HPC file system to which the authenticated user has authorized access and ensures compute node sanitation following completion of one project and prior to the start of the next.

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

References:

1. NIST Special Publication NIST SP 800 223, 2023, "*High Performance Computing (HPC) Security: Architectures, Threat Analysis and Security Posture*", NIST, https://doi.org/10.6028/NIST.SP.800-223.ipd (June 21,2024)
2. Peisert, S., 2015, DOE Workshop Report, *ASCR Cybersecurity for Scientific Computing Integrity - Research Pathways and Ideas Workshop*, DOE Workshop Report, Lawrence Berkeley National Laboratory, https://escholarship.org/uc/item/89s6w301 (June 21, 2024)
3. U.S. Department of Energy, Office of Science, 2015, *ASCR Cybersecurity for Scientific Computing Integrity, DOE Workshop Report*, (DOE) https://science.osti.gov/-/media/ascr/pdf/programdocuments/docs/ASCR_Cybersecurity_For_Scientific_Computing_Integrity_Report_2015.pdf (June 21, 2024)

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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 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. This is accomplished through BES support of five Nanoscale Science Research Centers and the world's largest suite of X-ray light sources 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, and at cost recovery for meritorious proprietary work. For additional information on BES user facilities, click here. The link to each facility's webpage leads to detailed descriptions of the experimental instruments and a listing of available experimental techniques.

An important objective of the BES program is to promote the transfer of the results of its basic research and advance the use of its world-leading tools to enable the development and demonstration of technologies important to 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. To that end, the DOE's Office of Technology Transitions provides the Laboratory Partnering Service to help researchers discover and partner with DOE's national laboratories. The DOE SBIR/STTR site under applicant resources also contains a resource for exploring collaboration with the national laboratories.

The SBIR/STTR program represents one important mechanism by which the BES program augments its university and laboratory research programs and integrates basic science, applied research, and development activities within the DOE. The BES program is currently interested in receiving applications on the following set of technical topics. For additional information regarding the BES programs, click here.

C59-03. IMPROVEMENTS IN OPTICAL METROLOGY FOR HIGH-PERFORMANCE VARIABLE-LINE-SPACING X-RAY GRATINGS

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

In support of high brightness and coherent X-ray light sources, advanced metrology instrumentation and analysis methods enable the production and verification of variable-line-spacing (VLS) X-ray diffraction gratings pushing toward diffraction-limited quality. These gratings are used in monochromators to spectrally separate and filter light at soft and tender X-ray photon energies. Formed on silicon substrates, they operate in glancing angles of incidence with high line density, typically 100 to 1000 lines per mm. A range of 1D line shapes from lamellar (square) to shallow blaze angles as small as 0.1 degrees are used. Various thin-film coating materials can be applied to promote high X-ray reflectivity.

Metrology instruments must possess the required performance and sensitivity to measure fine line positions across long grating substrates accurately. At this high precision, the interpretation of metrology data relies critically on a quantitative understanding of instrument characteristics in the spatial and spatial frequency domains (e.g., geometrical distortions, optical aberrations, instrument transfer function). By accounting for data perturbation caused by instrumental and optical limitations, significant improvements in the reliability, accuracy, and effectiveness of ex-situ optical metrology are expected. Such advances will enable improvements in producing high-quality X-ray gratings and contribute to improved modeling of predicted beamline performance.

Grant applications are sought in the following subtopics:

a. High-Precision Interferometric Microscopy with Stitching and Data Reconstruction

Proposals are sought in both hardware and software supporting high-performance optical metrology for variable-line-spacing (VLS) X-ray diffraction gratings. Metrology instrumentation is needed to provide precision and accuracy sufficient to enable 2D interferometric microscopy stitching measurements with sub-10-nm (rms) position accuracy over the VLS gratings. The gratings are fabricated on flat or curved substrates (with a local radius of curvature above 200 meter) reaching up to 0.5-meter length. The deliverables include a complete microscope interferometer stitching platform for VLS grating measurement. The platform must have user-friendly software for analyzing 1D and 2D metrology data. To achieve the most accurate VLS grating surface topography information possible, tools for calibration and deconvolution must be incorporated, or otherwise, the measured instrumental distortions must be explicitly accounted for.

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. Cocco, D., Sostero, G., Zangrando, M., 2003, "*Technique for measuring the groove density of diffraction gratings using the long trace profiler*," Rev. Sci. Instrum. 74, 3544, https://doi.org/10.1063/1.1584080 (June 21, 2024)
2. Siewert, F., Lammert, H., Reichardt, G., Hahn, U., Treusch, R., Reininger, R., 2007, "*Inspection of a Spherical Triple VLS-Grating for Self-Seeding of FLASH at DESY*," AIP Conf. Proc. 879, 667, https://doi.org/10.1063/1.2436150 (June 21, 2024)
3. Thomasset, M., Dvorak, J., Brochet, S., Dennetiere, D., and Polack, F., 2019, "*Grating metrology for X-ray and V-UV synchrotron beamlines at SOLEIL*," Rev. Sci. Instrum. 90, 021714, https://doi.org/10.1063/1.5055284 (June 21, 2024)
4. Siewert, F., Zeschke, T., Arnold, T., Paetzold, H., and Yashchuk, V., 2016, "*Linear Chirped Slope Profile for Spatial Calibration In Slope Measuring Deflectometry*," Rev. Sci. Instrum. 87, 051907 (2016) https://doi.org/10.1063/1.4950737 (June 21, 2024)
5. Yashchuk, V., Lacey, I., Arnold, T., Paetzelt, H., Rochester, S., Siewert, F., and Takacs, P., 2019, "*Investigation on Lateral Resolution of Surface Slope Profilers*," Proc. SPIE 11109, 111090M, . https://doi.org/10.1117/12.2539527 (June 21, 2024)
6. Xiong, X., Shimizu, Y., Chen, X., Matsukuma, H., and Gao, W., 2018, "*Uncertainty Evaluation for Measurements of Pitch Deviation and Out-of-Flatness of Planar Scale Gratings by a Fizeau Interferometer in Littrow Configuration*," Appl. Sci. 8, 2539, https://doi.org/10.3390/app8122539 (June 21, 2024)

7. Huang, L., Wang, T., Tayabaly, K., Kuhne, D., Xu, W., Xu, W., Vescovi, M., and Idir, M., 2020, "*Stitching Interferometry for Synchrotron Mirror Metrology at National Synchrotron Light Source II (NSLS-II),*" Optics and Lasers in Engineering 124, 105795, https://doi.org/10.1016/j.optlaseng.2019.105795 (June 21, 2024)
8. Vivo, A., Barrett, R., and Perrin, F., 2019, "*Stitching Techniques for Measuring X-ray Synchrotron Mirror Topography*," Rev. Sci. Instrum. 90, 021710,https://doi.org/10.1063/1.5063339 (June 21, 2024)
9. Yashchuk, V.V., McKinney, W. R., and Artemiev, N. A., 2013, "*Ex situ metrology of x-ray diffraction gratings*," Nucl. Instr. and Meth. A 710, 59, http://dx.doi.org/10.1016/j.nima.2012.10.109 (June 21, 2024)
10. Griesmann, U., Munechika, K., Renegara, T. B., Zheng, X. A., Soons, J. A., Chao, W., Lacey, I., Pina-Hernandez, C., Takacs, P. Z., Yashchuk, V. V., 2022, "*Characterization of surface texture-measuring optical microscopes using a binary pseudo-random array standard*," SPIE Proc. 12223, 1222306 . https://doi.org/10.1117/12.2633411 (June 21, 2024)
11. Rochester, S., English, D., Lacey, I., Munechika, K., and Yashchuk, V. V., 2022,"*Towards super-resolution interference microscopy metrology of x-ray variable-line-spacing diffraction gratings: Recent Developments*," SPIE Proc. 12240, 122400E, https://doi.org/10.1117/12.2633637 (June 21, 2024)

C59-04. START-UP SCHEMES FOR HIGH-EFFICIENCY SHORT-WAVELENGTH FREE ELECTRON LASER (FEL) SYSTEMS

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

High-efficiency Extreme Ultraviolet (EUV) and X-ray FELs based on strongly tapered undulators have shown substantial improvement in the sustainability of future X-ray FEL facilities. Strongly tapered undulators offer a more viable, practical solution to emergent compact industrial FEL applications. However, efficient beam deceleration in a tapered undulator requires a high-intensity input pulse, which is typically unavailable at short wavelengths. Direct laser seeding does not cover the spectral range of interest, and sub-harmonic seeding methods, such as high gain harmonic generation, significantly increase the cost and complexity associated with an FEL facility while restricting the overall system efficiency. As such, there is a need for innovative concepts that work in conjunction with strongly tapered undulators to enable high gradient power conversion and achieve greater than 5 % extraction efficiency at less than 200 nm wavelength. Two approaches are considered: developing an igniter scheme for high repetition rate FEL oscillators or tailoring the build-up on the signal over as few passes as possible starting from spontaneous emission.

This topic is focused on the experimental development of these innovative schemes in accelerator facility settings. In Phase I, the pre-bunching and/or efficient sub-harmonic seeding method should be demonstrated and optimized numerically in combination with the downstream high-efficiency FEL system. In Phase II, experimental proof-of-concept of the proposed scheme should be demonstrated at an accelerator laboratory and qualified with a greater than 5% efficiency in FEL performance. A complete system should be demonstrated in both phases, emphasizing optimized FEL oscillator efficiency. Proposals for seeding methods without a path to high efficiency and compactness will be considered unresponsive.

Grant applications are sought in the following subtopics:

a. Cost-Effective, Compact Igniter Scheme for High Efficiency FEL Systems

This subtopic seeks the development of innovative approaches for high-efficiency FELs where the high gradient power extraction is initiated from a low repetition rate intense signal that can be achieved using a harmonic multiplication or alternative microbunching scheme. The optimization of the system must include

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the analysis of the ensuing FEL cavity dynamics to achieve the target of greater than 5 % efficiency at short laser wavelength. The scheme should include the means to couple in the igniter pulse or the micro-bunched beam into the tapered undulator and trap the emitted radiation in the FEL oscillator cavity.

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

b. Build-Up in Oscillators with Tapered Undulator Systems

This subtopic is focused on assisting the build-up from low signal to very high circulating power in a tapered undulator-based FEL oscillator. Due to the undulator tapering, low signal gain would typically not be sufficient to overcome the losses and would not lead to significant power growth. Schemes can be developed to maximize the gain at the frequency of interest during pass-to-pass amplification to speed up the build-up as much as possible. The goal is to achieve high-efficiency power extraction (greater than 5 %) in a relatively small number of passes compared to the total number of pulses in the drive train.

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

References:

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C59-05. COST-EFFECTIVE OPTICAL SLOPE SENSOR FOR SURFACE METROLOGY OF X-RAY MIRRORS

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

In support of DOE's high-brightness X-ray light sources, grant applications are being solicited for developing technologies that support the development of a high-accuracy slope sensor for surface metrology and characterization of diffraction-limited X-ray mirrors. One of the required characteristics for these mirrors, to preserve the brightness and coherence of X-rays produced by diffraction-limited-storage-ring and free-

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electron-laser light sources, include highly curved reflecting surfaces (5-10 m) with surface slope tolerances better than 50 nrad, root-mean-square (rms) over the spatial range from sub-mm to the mirror clear aperture size.

Optical metrologists commonly use phase-measuring interferometry as an accurate and noncontact method to measure these aspheric or freeform surface shapes to guide the polishing process. However, this technique usually requires specifically designed, one-of-a-kind null optics. An alternative approach is slope measuring profilometry, which has been used to inspect X-ray mirrors since the 1980s. Instruments that use this method include the long trace profiler (commonly known as the LTP) and the Nanometer Optical Component Measuring Machine (NOM). NOM-like profilers are based on the most advanced industrial electronic autocollimator and have achieved very high accuracy (below 50 nrad) on flat X-ray mirrors.

The main drawbacks are the necessity to use a pinhole in front of the autocollimator's aperture to achieve a reasonable spatial resolution (approximately 1.5 mm) on the surface of the mirror under test and the inability to measure X-ray grating groove density at the Littrow condition.

To address this gap, grant applications are sought in the following subtopic:

a. High-Resolution Slope Sensor with Large Angular Range

This subtopic aims to develop an advanced slope sensor for the metrology of X-ray mirrors with sub-25 nrad rms precision over at least the 15 mrad angular range. The systems should be compact and easily integrable into new or existing X-ray metrology systems at synchrotron and other X-ray facilities and require minimal maintenance. The device's cost, size, slope measurement resolution, probe beam size at the sample location, and operational stability over several hours are primary considerations driving a new and innovative design.

Essential specifications that must be met include:

i. Precision of sub 25 nrad rms over a minimum of 15 mrad angular range
ii. Probe beam size 0.5 to 1.5 mm max.
iii. Operational stability over several hours.
iv. Providing sufficient light sensitivity for achieving the precision requirement on sub-25 nrad rms.
v. System size as small as reasonably possible, with a mass less than 10 kg.
vi. Acquisition rate of 100 Hz or higher.
vii. Total access to the raw image data for pre- and post-processing.
viii. Capability to trigger the measurement for on-the-fly scanning mode of operation.

Questions – Contact: Dava Keavney, Dava.Keavney@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: Dava Keavney, Dava.Keavney@science.doe.gov

References:

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C59-06. DRY ULTRA-LOW TEMPERATURE SAMPLE ENVIRONMENTS FOR SYNCHROTRON SOURCES

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

This topic seeks the development of closed-cycle sub-Kelvin measurement capabilities optimized for X-ray scattering beamlines to enable the study of quantum materials (QM) and quantum devices. Many quantum phases of matter that are of greatest significance to developing hardware for quantum information science applications (such as those hosting Cooper pairs, anyons, axions, or topological fermions) are stable only in sub-Kelvin temperature ranges. To access these temperatures, specialized refrigerators that utilize the Fermionic nature of 3He or the 4He/3He phase diagram are necessary. Such devices require significant infrastructure, are often built inside 'wet' He-consuming cryostats and have numerous thermal and vacuum shielding layers around the sample space. These conditions have traditionally limited the feasibility of using such systems with X-ray probes due to the intensity losses and significant background signals generated at most X-ray energies by parasitic scattering from the shielding.

Similarly, X-rays' relatively strong interaction with matter also leads to beam heating at the sample position, typically between 0.1 – 1 mW, which can render sub-Kelvin temperatures unstable upon illumination.

Furthermore, 3He and dilution refrigerators are often bulky and immobile and consume significant amounts of liquid He to achieve and maintain their base temperatures. Yet, they only provide modest cooling power at their base temperature, limiting their practical cooling capability. A greater cooling capability in the mW range would enable their use with more strongly interacting probes and additional experiment sample conditions that are not currently feasible. Developing dry sub-Kelvin systems optimized to the needs of X-ray scattering beamlines would allow the study of structure, local order, charge order, and dynamics inside these quantum phases and significantly improve the understanding of QM. Such a system would need to minimize parasitic scattering, overcome X-ray beam heating, and be compact and portable.

Grant applications are sought in the following subtopics:

a. Development of a Compact X-Ray Synchrotron Beamline Compatible Dry ^{3}He Refrigerator

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Grant applications are sought to develop a dry ^3He system for operation at high energy (approximately 100 keV) synchrotron X-ray scattering beamlines. The refrigerator should satisfy the requirements given in the topic introduction. The device should achieve a base temperature of 300 mK with a cooling power at base temperature of approximately 1 mW (or enough cooling power to overcome approximately 1 mW of active beam heating on the sample anticipated for a 100 keV beam with flux approximately $1x10^{12}$ photons/s/mm^2) and a hold time of > 6 hours; have temperature control from base to 50 K, minimize X-ray scattering cross-section of heat shielding in the beam path, allow for 180 degrees of rotation/scattering angle while in use, maintain vibration at sample position of less than 0.1 mm, allow for mounting from the bottom of the device, have ports for optical/electrical feedthroughs to support experimental calorimetry, and have a height approximately 5.5 ft or less.

Questions – Contact: Dava Keavney, Dava.Keavney@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: Dava Keavney, Dava.Keavney@science.doe.gov

References:

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C59-07. ADVANCED NEUTRON BEAM OPTICS TECHNOLOGIES

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

Developments are sought that improve the performance or manufacturing techniques of technology used in manipulating thermal and cold neutron beams for scattering instrumentation. These developments mainly support anticipated upgrades to instruments at existing neutron sources and future spallation and reactor sources in support of our nation's materials development mission. Desired technologies fall into two categories: neutron polarizers and neutron monochromators. Both technologies support manipulating incident neutron beams and scattered neutron signals across various instrument techniques. A domestic supplier of advanced neutron beam optics technologies is critical to advancing and sustaining world-class scattering instrumentation within the BES Scientific User Facility portfolio.

Grant applications are sought in the following subtopics:

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a. Neutron Polarizers and Analyzers Using Magnetic Thin Films

Thermal and Cold neutron beams can be used to understand magnetic ordering across a range of length scales. Depending on the specific scattering application, technologies are used to polarize the incident neutron beam and/or analyze the scattered neutron field with instruments focused on understanding magnetic materials.

Key requirements are:

i. Coated surfaces should be able to reflect neutron wavelengths of 2.0 Å up to 0.8° grazing incident angle (m=4) with reflectivity greater than 80%.
ii. Polarizing surfaces should provide a polarization efficiency of 90% or better.
iii. Typical beam cross-section dimensions range from 4 cm to 15 cm.
iv. The volume within any enclosed polarizing element should maintain a vacuum less than 1 mbar or be purged with He; non-enclosed elements should be able to reside in an evacuated or purged enclosure.

Questions – Contact: Mikhail Zhernenkov, Mikhail.Zhernenkov@science.doe.gov

b. Neutron Monochromators and Energy Analyzers

Neutron Monochromators that can scatter beams with energy resolution on the order of 1% or finer are critical to many neutron scattering instruments. Monochromatic crystals must have a consistent neutron mosaic at Miller indices relevant to the energy-resolving need when developing scattering instrument designs.

Key requirements are:

i. The use of Highly Ordered Pyrolytic Graphite (HOPG), Single Crystal Silicon, Germanium, or Diamond with reflectivity greater than 70% for wavelengths as short as 1 Å.
ii. Consistently meet a specified mosaic as narrow as 10 arcminutes and as large as 100 arcminutes to within 10% for neutron scattering from the Miller index of interest.
iii. Geometries as large as 15 cm x 5 cm x 0.4 cm are needed to accommodate a range of possible scattering instrument designs and capabilities.

Questions – Contact: Mikhail Zhernenkov, Mikhail.Zhernenkov@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: Mikhail Zhernenkov, Mikhail.Zhernenkov@science.doe.gov

References:

1. M. Popovici, A.D. Stoica, C.R. Hubbard, S. Spooner, H.J. Prask, T.H. Gnaeupel-Herold, P.M. Gehring, R.W. Erwin, 2001, "*Multiwafer focusing neutron monochromators and applications*," Proc. SPIE 4509, 21, https://doi.org/10.1117/12.448073 (June 21, 2024)
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C59-08. NANOMATERIAL-INTEGRATED MICROELECTRONICS FOR IR DETECTION AND IMAGING

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

We seek the development of a commercially viable system to provide high sensitivity, energy-efficient detection of shortwave infrared wavelengths. The shortwave infrared (SWIR) spectral region refers to a range of wavelengths spanning roughly 1 to 2 μm. This region lies slightly beyond the wavelengths visible to the human eye. By capturing images in SWIR, valuable chemical and environmental data can be obtained for various systems that are not accessible using visible light alone [1,2,3]. Consequently, SWIR imaging is critical in many industries, such as semiconductor manufacturing and agriculture. In the semiconductor industry, SWIR imaging devices have emerged as power inspection tools to monitor the quality and reliability of integrated circuits. By penetrating Si and other semiconductors, these devices offer non-destructive, real-time detection of interconnects damage and misalignment, micro-cracks and point-like defects, and other parameters used for metrology of semiconductor wafers. A reduction in cost can allow broader integration of SWIR sensors and cameras at various stages of the manufacturing process leading to improved yields, optimized processes, and enhanced overall productivity [4]. While Silicon (Si)-based sensors are the most common photodetectors, they are only photosensitive to wavelengths up to approximately 1000 nm and thus do not work in the SWIR. The most common SWIR detectors and cameras utilize InGaAs for the photodiode layer, which exhibits a quantum efficiency (QE) of 60-80% between 950 and 1650 nm. Unfortunately, InGaAs and other SWIR detectors also exhibit several inherent shortcomings that greatly limit their general use [1,2,3]. These include much larger dark count noise [5] that requires power-draining cryogenic cooling, large pixel sizes, and complicated fabrication procedures [6] that ultimately result in expensive sensor chips that cost $5k-$20k per unit, or $20k-$50k for cameras fully integrated with cooling and accessories. Recent advances in the development of upconverting nanomaterials, including those that demonstrate photon avalanching, present an opportunity to overcome many of these challenges.

Grant applications are sought in the following subtopics:

a. Development of a Commercially Viable System for IR Detection and Imaging Via Nanomaterial-Integrated Microelectronics

In this subtopic, we seek proposals for the development of a system that capitalizes on the unique properties of novel nanomaterials for high-sensitivity and energy-efficient SWIR detection. New upconverting nanoparticles (UCNPs) and avalanching nanoparticles (ANPs) can convert SWIR wavelengths between 1 μm and 1.8 μm into wavelengths detectable by Si (less than 1 μm) [7,8,9]. Further, these new nanomaterials can dramatically increase the historically inefficient UC process (usually 1%) up to 40% [7,8]. This giant leap in QE invites novel UCNPs and ANPs to be a serious contender in SWIR imaging. ANP- and UCNP-enabled SWIR cameras, in which a layer of NPs is integrated with a Si sensor, could offer all the benefits of Si-based detectors without compromising on SWIR performance. These benefits include significantly lower noise, no need for cooling, high-quality pixels, and high pixel density (high resolution) – all at much lower cost than existing SWIR detector technologies. These properties would render ANP-enabled SWIR cameras advantageous to many current application spaces including silicon wafer inspection, plastic and glass sorting, defense and surveillance, and light ranging and detection, but also open new markets that previously avoided SWIR due to prohibitively high cost, high energy usage, and/or lack of sensitivity.

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Phase I deliverables should demonstrate the detection of IR photons in the range of 1150-2000 nm, using a Si detector (not necessarily integrated) to detect emission at wavelengths less than 850 nm. Key performance parameters will be signal to noise sensitivity, read noise, and dark current levels comparable to current InGaAs systems under identical conditions.

Phase II deliverables include a prototype of an integrated sensor based on a Si charge coupled device (CCD) that can acquire a digital image from an incident IR test pattern (1150-2000 nm). This could, for example, include a smooth film integrated with a 2D silicon CCD. The prototype should demonstrate sensitivity, uniformity, and energy efficiency at a level better than comparable InGaAs detectors.

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. M. P. Hansen and D. S. Malchow, 2008, "*Overview of SWIR detectors, cameras, and applications*," in SPIE Defense and Security Symposium, International Society for Optics and Photonics, 69390I, https://doi.org/10.1117/12.777776 (June 21, 2024)
2. B. Stark, M. McGee, and Y. Chen, 2015, "Short wave infrared (SWIR) imaging systems using small Unmanned Aerial Systems (sUAS)," 2015 International Conference on Unmanned Aircraft Systems (ICUAS), Denver, CO, USA, 495, doi: 10.1109/ICUAS.2015.7152328 https://ieeexplore.ieee.org/document/7152328 (June 21, 2024)
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9. Skripka, M. Lee, X. Qi, J.-A. Pan, et al, 2023, "*A generalized approach to photon avalanche upconversion in luminescent nanocrystals*," Nano Letters 23, 7100,https://doi.org/10.1021/acs.nanolett.3c01955 (June 21, 2024)

Additional information:

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The five Nanoscale Science Research Centers (NSRCs) are DOE's premier user facilities 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 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/

C59-09. CORROSION TOLERANT AND COST-EFFECTIVE ALLOYS FOR REVERSIBLE SOLID OXIDE FUEL CELL SYSTEMS

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

Elevated temperature electrochemical systems, currently being developed for power generation and hydrogen production, in configurations representing reversible solid oxide fuel cells (R-SOFCs), offer potential to achieve improved system efficiency, ease of integration with renewable resources and nuclear energy, and use of conventional materials for the construction for electrochemically active and in-active cell and stack components, as well as balance of plant sub-systems. R-SOFC cells and cell stacks, in general, utilize a thin, dense, solid ion conducting (H^+, $O^=$) electrolyte, porous oxygen and fuel electrodes, dense metallic interconnect, gas separation seals, and porous support (metallic, ceramic). Balance of plant sub-systems include mechanical, thermal, and electrical sub-systems. Commonly available materials and fabrication systems have been utilized successfully for the fabrication of cells and stacks.

Long term operation of the above systems indicates that, though the performance and efficiency remain as postulated, the metallic cell and stack components show the surface oxidation and bulk corrosion of the metal alloys leading to performance degradation (changes in ohmic and non-ohmic losses in the cell). Breakdown of the surface passivation leads to metal loss and changes in mechanical properties, as well as changes in the alloy composition and structure. Alloy chemistry in terms of the type and content of alloying additives along with systems operating parameters such as exposure temperature, temperature distribution, exposure fuel and oxidant gas chemistry, and gas phase contaminants are attributed to influence the corrosion of the metal.

Grant applications are sought in the following subtopic:

a. Development of Corrosion-Resistant R-SOFC Cell and Stack Components

Applications are sought for a research program aimed at advancing (a) the understanding of metal component degradation processes in R-SOFC cells and stacks above 90% of steam concentration at high temperature (600 °C to 900 °C), (b) development of mechanisms responsible for accelerated bulk, interface and surface degradation, (c) experimental validation of the proposed mechanisms, and (d) identification of corrosion mitigation approaches, including tailoring of alloy chemistry, system operating conditions, and corrosion passivation schemes. It is envisioned that the identified mitigation approaches will be subsequently examined and experimentally validated for process scale up, long term stability, and cost effectiveness.

The outcome of a phase I research project will be the identification of R-SOFC cell and stack component corrosion mechanisms and experimental evaluation and characterization of metallic corrosion at button cell and bench scale level for up to 500 hours under simulated steam electrolysis (above 90% steam concentration) R-SOFC operating conditions (600 ℃ to 900 ℃). Cost effective and scalable approaches for corrosion mitigation will be identified, and mechanical and electrical properties of cell components will be evaluated.

The outcome of a phase II research project will include optimization and selection of scalable and cost-effective alloy chemistry and manufacturing processes (i.e., surface finishing, heat treatment, shaping, joining, and others) for cell and stack components (approximately 100 to 150 cm^2 or larger active cell area), followed by experimental evaluation of the long term (2000-2500 hours exposure) corrosion behavior in a 5-cell stack (nominal systems operating conditions). Chemical, mechanical, and electrical properties and related changes will be monitored and compared with the current state of the art. A commercialization plan for large scale manufacturing (in consultation with alloy and R-SOFC systems manufacturers) will be developed.

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

1. P. Alnegren, M. Sattari, J. Froitzheim, J-E. Svensson 2016, "*Degradation of ferritic stainless steels under conditions used for solid oxide fuel cells and electrolyzers at varying oxygen pressures*" Corrosion Science, Volume 110, September 2016, Pages 200-212 https://www.sciencedirect.com/science/article/abs/pii/S0010938X16301810 (July 1, 2024)
2. Jingwen Mao , Enhua Wang , Hewu Wang , et al, 2023, "*Progress in metal corrosion mechanism and protective coating technology for interconnect and metal support of solid oxide cells*" Renewable and Sustainable Energy Reviews Volume 185, October 2023, 113597 https://www.sciencedirect.com/journal/renewable-and-sustainable-energy-reviews (June 21, 2024)
3. Shuai He, Yuanfeng Zou, Kongfa Chen, San P. Jiang, 2023, "*A critical review of key materials and issues in solid oxide cells*" https://doi.org/10.1002/idm2.12068 (June 21, 2024)
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C59-10. ADVANCED SUBSURFACE ENERGY TECHNOLOGIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I 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 safe and efficient development of subsurface resources for the geologic storage of captured carbon dioxide (CO_2). 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.

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The Department of Energy's (DOE) Office of Basic Energy Sciences (BES) is teaming with the Geothermal Technologies Office (GTO) and Office of Fossil Energy and Carbon Management (FECM) to advance the state of the art for continued development of subsurface energy sources in a safe and sustainable manner through the focus areas and subtopics listed below. The goals of these subtopics are to a) develop advanced methods to inhibit mineral scaling within geothermal systems; b) develop improved sensors, electrode systems, and/or other system components for deep well applications of subsurface electromagnetic (EM) monitoring; and c) develop new digital tools for the conceptual design and early process configuration planning of CO_2 conditioning equipment to mitigate excess oxygen concentrations within CO_2 transport systems.

Grant applications are sought in the following subtopic:

a. Geothermal

This subtopic focuses on inhibition of scaling in geothermal systems. 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 (greater than 390°F or approximately 200°C) for purposes of energy production.

Mineral scaling in geothermal systems can cause challenges within the reservoir, wellbores, and surface equipment associated with geothermal energy production. Various minerals in geothermal brines such as silicates, carbonates, sulphates, etc., can precipitate within rock fractures, on casing in the wellbores, and within surface equipment such as pipes and turbines because of temperature changes in the geofluid. This precipitation leads to scaling and loss of process efficiency as flow is constricted or redirected, above and below surface level.

Several methods currently exist to mitigate scaling issues, including acid injection, mechanical removal, and pH modification of the geothermal brine to inhibit mineral scaling. Many of these processes can require shutdown of wells or surface equipment and/or are administered on an intermittent basis, reducing their effectiveness.

GTO is seeking projects to develop advanced methods for inhibition of mineral scale from geothermal brines that are more effective than the current state-of-the-art in terms of effectiveness, efficiency, cost, and environmental considerations. This could include innovative chemical treatments, application of advanced materials such as superhydrophobic coatings, or other means to effectively deal with mineral scaling in geothermal reservoirs, wellbores, and surface equipment.

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).

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 inhibition of mineral scaling within geothermal systems. Applications focusing on scale mitigation or removal via traditional technologies, ground source heat pumps, direct use applications, or gathering of data that is not of interest under this subtopic via surface/downhole sensors will be deemed non-responsive.

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Questions – Contact: William Vandermeer, william.vandermeer@ee.doe.gov or Michael Weathers, michael.weathers@ee.doe.gov

b. Geologic Storage of CO_2

This subtopic focuses on development of improved sensors, electrode systems, and/or other system components for deep well applications of subsurface electromagnetic (EM) monitoring. The FECM Carbon Transport & Storage Program is focused on developing and commercializing fit-for-purpose geophysical systems that can accurately and affordably help monitor CO_2 injected into the deep subsurface during a commercial-scale carbon capture and storage (CCS) operation (>1 million metric tons per year). Accurate monitoring at a carbon storage site is necessary to track the movement of CO_2 and assure permanence for geologic storage. Seismic and electrical geophysical methods are key methods for monitoring plume movement far from the injection wells. Electromagnetic (EM) techniques are of particular interest because they have the potential to provide a more precise measure of CO_2 saturation than seismic techniques and may be applicable where seismic methods have poor utility. However, the spatial resolution of measurements using currently available EM systems is much lower than that of seismic systems. EM monitoring systems include frequency-dependent transmitters and receivers, which measure the elective and induced magnetic fields in the subsurface. EM system configurations can include surface, borehole, or surface-to-borehole configurations. It is not currently considered feasible to require that all wells in a storage project have non-metallic casings. Therefore, the ability to produce high resolution EM data in deep reservoirs using EM system configurations incorporating metallic well casing remains a significant R&D challenge.

Grant applications are sought for novel or improved, reliable, rugged EM sensors, electrode systems, or other system components – including generic system designs and deployment methods -- for deep borehole/well deployments for monitoring the locations of deep subsurface CO_2 plumes. Additional capabilities of interest include the ability to detect and locate upward displaced native brines in lower salinity aquifers, the ability to locate zones of open natural fractures below or in the reservoir and/or through the caprock, and the ability to help spatially estimate the CO_2 saturations in deep subsurface CO_2 plumes. The deep subsurface system components may be deployed permanently or temporarily (via retrievable and re-installable components). The system should be capable of monitoring plume movement at depths where ambient fluid pressures would keep the CO_2 in a dense phase, with depths ranging up to 12,000 feet. Ideally, the EM monitoring system should be maintainable in its operations for 30 years or more. System design should take into consideration the need for critical component redundancy or replacement due to failure. Deployment and operation should minimally interfere with other monitoring measurements and take into consideration the use of metallic casing versus non-metallic casings and shared usage of downhole space, energy supply, data transmission cables, mounts and fasteners, deployment methods/opportunities, etc.

Previously (FY 2023), DOE funded SBIR projects to develop turn-key systems and services that facilitate easier, better, higher-resolution data acquisition and interpretation of seismicity risks, leakage risks, and/or CO_2 plume location(s) using one or more electrical resistivity, magnetotelluric, self-potential, and/or 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. Awarded projects noted that the costs of EM systems are slightly higher than the current market will support and noted the need for cost reductions and resolution improvements. With this current FY 2025 solicitation, DOE seeks the development of components that improve resolution of EM techniques through the deployment of electrodes and/or sensors in deep boreholes at or near the storage reservoirs, typically between the depths of 2,600 ft and 12,000 ft below the ground surface. System components may be deployed

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during the construction or abandonment of stratigraphic test wells, in built-for-purpose monitoring wells, and/or in repurposed pre-existing wells (e.g., legacy oil and gas wells). Well-to-well designs and well-to-surface designs may be addressed. While the focus of projects should be on the development of system components (hardware), some of the proposed effort (and DOE funding) can address overall system design, deployment options/methods, and data handling & processing software (but excluding interpretation of the data).

Commercial CO_2 storage sites are anticipated to include several newly drilled monitoring and injection wells and may or may not have available legacy wells. Casing or injection tubing material, especially in the injection zone, is anticipated to be chromium steel, which has a lower conductivity and less magnetic permeability than soft iron steel. The site geometries will range from less than one square mile in area to several square miles in area, and injection zones or strata are anticipated to be one or more layers totaling tens of meters in thickness and 6% to 30% porosity.

Several topics are of high interest:

- Hardening permanent sensor arrays to last at least 5 years and up to 30 years.
- Designing permanently installed arrays where data may be collected automatically and unattended. These arrays may be source or receiver components.
- Design of field acquisition to provide good sensitivity in the injection zone and the potential to monitoring changes at the boundaries of the CO_2 plume.
- The use of capacitively coupled electric field elements that may collect e-field data without direct contact to the formation. This may be beneficial if electrode elements dry out.
- The use of casing electrodes where the well casing in an observation or monitoring well in the injection zone is used as an electrode.
- The design of downhole data acquisition platforms where collected data is digitally sampled and averaged prior to collection.
- The potential use of slim holes for monitoring wells.

Questions – Contact: Mark McKoy, mark.mckoy@netl.doe.gov

c. CO_2 Transport Systems

This subtopic focuses on the development and commercialization of new digital tools for the conceptual design and early process configuration planning of CO_2 conditioning equipment to mitigate excess oxygen concentrations within CO_2 transport systems. This topic seeks to develop new digital tools that can support the early conceptual design and process configuration of CO_2 conditioning equipment related to treating elevated oxygen gas (O_2) concentrations in captured CO_2 streams so that these streams meet transportation and storage CO_2 quality specifications.

To address DOE's need for accelerating commercial liftoff in carbon management, new digital tools and technologies are desired to assess, evaluate, predict, and potentially monitor the asset integrity of carbon transportation system hardware and individual components (e.g., booster equipment, pipelines, casing and tubing) when exposed to carbon dioxide with various impurities and operating conditions throughout an asset's design life.

The proposed project encompasses tool development to address potential asset integrity threats related to higher than desired trace oxygen gas concentrations within a CO_2 stream and its reduction to a desired concentration of less than 10 ppm-mol. The project should consider or include current state of the art removal technologies and consider or include potential technologies in early-stage development that may become applicable.

The result sought will be a digital tool that can be applied either as a plug-in or stand-alone tool that supports the early-stage or feasibility design and process configuration of CO_2 conditioning facilities, estimating equipment scope and costs along with inlet, product, and waste stream compositions, and determining any co-benefits of treating other impurities that may also require removal to meet material integrity and/or product quality specifications for various CO_2 sources such as oxy-fuel, post combustion capture (PCC) and precombustion capture, and direct air capture (DAC) product streams.

Questions – Contact: Kevin Dooley, kevin.dooley@hq.doe.gov

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C59-11. HIGH PERFORMANCE MATERIALS FOR NUCLEAR APPLICATION

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

Grant applications are sought in the following subtopics:

a. 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, tests conducted on PM-HIP structural materials showed that while some of 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, and/or other factors.

Applications are sought to understand the cause of the property degradation and to develop an improved PM-HIP process for high-temperature alloys, including, but not limited to: powder chemistry specification, powder manufacturing, powder storage, container manufacturing, container filling and outgassing, hipping parameters, and container removal, so that the high-temperature properties, including fatigue, creep, and

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creep-fatigue properties of the fabricated components, are the same as, or exceed, those of wrought product for very long design lifetimes.

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

b. Advanced Materials for Structural Applications

Revolutionary technologies in crosscutting materials science have the potential for radical improvement in reactor or fuel cycle performance, safety, and economics. The emerging fleet of advanced reactors is supported by its strongest business case when coupled with advanced materials and manufacturing techniques that offer enhanced performance and/or significant reductions to the costs of original construction and major component replacement. The concepts under consideration include advanced materials and/or classes of materials, and advances in manufacturing with applications ranging from components through complete factory fabrication of reactors for delivery and installation at the site.

NE is seeking proposals for R&D to better understand core and structural materials and consider new manufacturing concepts and capabilities, advance testing of existing materials, and to explore and develop new classes of materials for the development of nuclear applications, equipment, testing capabilities, materials, or components manufactured using such techniques. Topics of interest include, but are not limited to, processing and fabrication methods for composites, concrete, and metals; joining and repair; and components, sub-systems, systems, structures, and non-destructive examination.

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

c. Other

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

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

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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, the National Microbiome Data Collaborative (NMDC) centered on microbiome standards and metadata 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.

C59-12. ATMOSPHERIC MEASUREMENT TECHNOLOGY

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

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, independence, and prosperity. The mission of the Earth and Environmental Systems Sciences Division (EESSD) within BER is to enhance the sub-seasonal to centennial predictability of the Earth system using long term field experiments, DOE user facilities, modeling and simulation, uncertainty characterization, best-in-class computing, process research, and data analytics and management (Reference 1). EESSD scientific grand challenges include the integrated water cycle, biogeochemistry, high latitudes, drivers and responses in the earth system, and data-model integration (Reference 1).

To address these scientific grand challenges, data from field campaigns and long-term observations of atmospheric properties are needed to quantify atmospheric variables and study processes that are important to climate such as aerosol, cloud, and precipitation formation; boundary layer processes that affect aerosol and cloud formation and properties; and aerosol-cloud-precipitation-radiation interactions and feedbacks.

This topic is specifically focused on developing technologies for robust and well-characterized measurements of: downwelling radiation; aerosol size distribution, chemical composition, and optical properties; cloud and precipitation microphysical, macrophysical, and optical properties; column water vapor or liquid water path; and details of atmospheric structure and variability including vertical profiles of turbulence, temperature, trace gas, wind, vertical velocity, cloud liquid or ice, and water vapor. These data are necessary both for fundamental process understanding and for evaluation of numerical models that are used to assess the predicted impacts of climate change on global and regional systems (References 2-7).

Proposed technologies must be suitable for deployment under realistic operating conditions at long-term ground-based measurement sites such as those operated by the Atmospheric Radiation Measurement (ARM) user facility (www.arm.gov and Reference 6) and the Ameriflux program (https://ameriflux.lbl.gov/), on airborne research platforms (https://arm.gov/capabilities/observatories/aaf/; Reference 8), or on ship-based platforms. Therefore, applications must consider and discuss factors such as the size, weight, and power; data logging; calibration procedures; maintenance requirements; ability for autonomous or remote operation; motion stabilization; and/or other factors critical to successful operation of the proposed technology in realistic field conditions.

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Applications should demonstrate performance characteristics of proposed measurement systems and must propose Phase I bench tests of critical technologies ("critical technologies" refers to components, materials, equipment, or processes that overcome significant limitations to current capabilities). In addition, grant applications must (1) specifically describe how the proposed work is a technical advance over existing commercial instrumentation and how it will either improve the robustness, automation, precision, accuracy, calibration, resolution, sampling rate, or weight/power requirements compared to existing instrumentation or provide measurements of atmospheric parameters not currently available with existing commercial instrumentation and (2) identify a path towards field deployment of the proposed technology.

Grant applications for development of new instrument components or instrument systems, and applications that propose only computer modeling without physical testing will be considered non-responsive. Grant applications must provide convincing documentation (experimental data, calculations, and/or simulations as appropriate) to show that the proposed sensing method is appropriate to make the desired measurements.

Approaches that leave significant doubt regarding sensor functionality in realistic field conditions will not be considered. Applications that do not focus on measurement of at least one of the atmospheric variables described above or that do not clearly describe relevance of the proposed measurement technology to the scientific goals of the EESSD division will not be considered.

a. Coarse Mode Aerosol Instruments

Measurements of coarse mode atmospheric aerosols are challenging due to instrument limitations, lack of observations, and the complex processes involved in their generation and throughout their lifetime. Coarse mode aerosols have significant effects on aerosol-radiation interactions and the formation of warm and ice clouds. Common coarse mode aerosols—dust, sea salt, and bioaerosols—participate in important atmospheric processes such as cloud condensation nuclei (CCN) formation and ice nucleation, and they are often released from surface sources, making measurements close to the ground especially important, though they can be transported considerable distances if lofted sufficiently high.

Many instruments purporting to measure coarse mode aerosols do not reach aerodynamic diameters of even 10 µm, and fewer still measure coarse mode aerosol properties above that diameter. Coarse-mode aerosol speciation is challenging with existing instruments because their often non-refractory composition does not thermally desorb at 600°C, and they therefore cannot be measured by commonly used commercial aerosol mass spectrometers. Systems that use a laser pulse instead of a thermal vaporizer might be able to blow the particle apart, but they break apart delicate molecules in or on particles, thereby eliminating information that is also of interest. Many techniques exist for capturing particles on a variety of media and determining various aspects of their composition and size using a variety of microscopic and analytical techniques, but these techniques suffer from poor time resolution, artifacts introduced by the substrate used to capture these particles, and manual analysis procedures that limit analyses to a few hundred or perhaps a few thousand particles at most.

Optical characterization of coarse mode particles meets with a variety of difficulties. Digital holography (e.g., reference 21) offers one potential avenue for sizing large particles, but the performance of this technique falters below a few microns in size. Below this size, optical sizing techniques often suffer due to uncertainties in particle shape and refractive index.

Continuous, real-time measurements of particular interest are:

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- Coarse mode size spectra, especially those that can push upper size limits well above 3 µm, preferably up to and above 10 µm diameter particles,
- Composition of coarse mode particles,
- Single particle size and composition measurements of coarse mode particles
- Automated size spectra and/or composition characterization of coarse mode particles, and
- Other properties of coarse mode particles such as their ability to form cloud condensation nuclei (CCN), ice nucleating particles (INP), and their optical properties.

Questions – Contact: Jeff Stehr Jeff.Stehr@science.doe.gov

b. Biological Aerosol Instruments

Perhaps more challenging than coarse mode aerosols in general are bioaerosols, which can swell and shatter into fragments that are themselves capable of nucleating cloud and ice particles and may no longer be coarse mode particles. Existing techniques offer minimal species information or may require well trained specialists analyzing particles collected over long time intervals to determine biological or chemical species. Other techniques measure particle fluorescence, requiring additional instrumentation to assess whether particles are truly biological in origin or simply nonbiological particles that fluoresce.

Continuous, real-time measurements of particular interest time are:

- Biological species of atmospheric bioaerosols,
- Size spectra of bioaerosols up to 30 µm, and
- Composition of bioaerosols, especially as a function of size.

Questions – Contact: Jeff Stehr Jeff.Stehr@science.doe.gov

c. Autonomous Unattended Atmospheric Measurements from Marine Platforms

Marine regions are important to climate but are highly under sampled due to the expense of ship-borne field campaigns. Deploying instruments on commercial ships provides a unique opportunity for expanding observations of marine regions but creates significant challenges for measurements. Existing initiatives such as the National Oceanic and Atmospheric Administration (NOAA) Ship of Opportunity Program (SOOP; https://www.aoml.noaa.gov/phod/soop/index.php) and the Science Research on Commercial Ships (Science RoCS; https://sciencerocs.org/) initiative have deployed basic meteorological sensors and oceanographic instruments on commercial ships. However, few existing commercial instruments are suitable for making unattended aerosol, cloud, or atmospheric state measurements on marine platforms. A recent BER workshop discussed high priority ship-borne measurements as well as challenges in unattended autonomous shipborne operations (https://science.osti.gov/-/media/ber/pdf/workshop-reports/2024/BER-ShipObservationsReport-16May2024-DRAFT.pdf).

This subtopic seeks technologies for autonomous measurement of aerosol, cloud, precipitation, or atmospheric state properties that are suitable for unattended operation on marine platforms such as commercial ships, barges, or buoys for at least 1-week periods. Measurements of particular interest are:

- Mobility-based aerosol size distribution from 10 – 800 nm,
- Turbulence/updraft velocity profiles from near-surface to 1000 m above surface level,
- Planetary boundary layer height,
- Cloud optical depth,

- Aerosol composition, and
- Cloud condensation nuclei.

Applications must describe proposed innovations that will make the measurement systems suitable for unattended autonomous operations on marine platforms (i.e., barges, buoys, or ships) and how the proposed measurement system is an advance over existing commercial instrumentation.

Highly desired elements include:

- Hardening for marine deployments
- Modular, stand-alone systems
- Technologies for minimizing effect of ship motion, tilt, or vibration on instrument performance
- Automated self-cleaning of instruments
- Autonomous calibrations
- Diagnostic software for remotely monitoring instrument performance
- Software for automated quality assurance/quality control
- Procedures for automated or remote shutdown of instruments
- Autonomous flow control for aerosol instruments
- Instrumentation that does not require hazardous materials (butanol, x-ray or other radioactive sources, etc.) for operation
- Appropriate, well-characterized inlets for aerosol measurements
- Ability to conditionally sample aerosol measurements by wind direction and/or screen out ship exhaust measurements

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

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C59-13. 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 Phase I Applications: YES	Accepting STTR Phase I 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) programs 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 program spans 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) programs combined with DOE User Facilities (such as the

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Joint Genome Institute https://jgi.doe.gov/ and the Environmental Molecular Sciences Laboratory https://www.emsl.pnnl.gov/science) 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 for 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, protein structures, 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.

Currently, 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, data integration across data types including current omics and new categories related to organism and biosystem function and phenotype, including computational and chemical imaging in 2 and 3 dimensions, and chemical communication between organisms. 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 and computational approaches correlating protein structural data with genome sequencing and functional information 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

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C59-14. ENABLING TOOLS FOR MOLECULAR STRUCTURE OR MORPHOLOGICAL CHARACTERIZATION OF BIOLOGICAL AND BIOGEOCHEMICAL INTERACTIONS WITHIN OR AMONG MICROBES, PLANTS, MINERALS, SOILS

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

BER supports research across scales to support missions in scientific discovery and innovation, energy security, and environmental responsibility. BER's Biological Systems Science Division (BSSD) seeks to understand the fundamental genome-encoded properties of plants and microbes that can be harnessed or redesigned for optimizing the production of biofuel and bioproducts. Functional interpretation of genomic information often requires additional molecular level characterization of individual proteins, protein assemblies and their interactions. Characterization of the structure and dynamics of the macromolecules responsible for plant and microbial interactions, and rhizosphere processes, can provide insights into metabolism, molecular interactions, and function that aren't evident from genomic information. Structural and morphological characterization of organelles, cells and tissues provide insights into strategic spatio-temporal organization and process hierarchy. The knowledge described above is necessary for planning and designing optimized biological systems to meet BER mission needs.

BER's Environmental Systems Science program area examines complex ecological and hydro-biogeochemical processes within terrestrial and coastal systems to understand inherent and emergent properties of changes to Earth and environmental systems. Biogeochemical processes underlie the transport and transformation of nutrients; carbon sequestration and storage; and other molecular processes that impact the environment. Because oxidation-reduction reactions govern these critical processes, characterizing the chemistry and speciation of the molecular components gives insights into their participation in important environmental functions.

BER supports and provides access to powerful experimental approaches for structural, dynamic and morphological characterization at scales from angstrom to millimeters, and temporal information in a range of femtoseconds to hours. The techniques available, which use electrons, photons, or neutrons as the interrogating probe, can be accessed for free at DOE Office of Science user facilities where BER supports access, training, and user support for a variety of experimental capabilities. These BER-supported capabilities are freely available to all researchers through peer-reviewed facility application processes. They are described at http://www.BERStructuralBioPortal.org.

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This SBIR-STTR topic encourages the development of tools necessary for taking measurements on BER mission experiments using the experimental capabilities described at http://www.BERStructuralBioPortal.org.

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

This subtopic solicits the development of robust tools for improving beamline-based or cryo-EM-based structural biology and imaging capabilities for researchers studying microbial, plant, rhizosphere or environmental systems, or their components, relevant to BER mission interests (see https://genomicscience.energy.gov/ and https://ess.science.energy.gov/). An explanation of how the proposed technical development can be coupled to biological or biogeochemical objectives must be included. Plans for technical validation in biological or biogeochemical space of the proposed technology should be clearly described.

For this solicitation, tools, devices, or automation can be proposed for characterizing targets at or within the scale of atomic to multi-cellular and small ecosystem. Technology areas include Facility-based x-ray, neutron or infrared beamline-based techniques and cryo-electron microscopy or tomography, or micro-electron diffraction, for determining the 3D structures of macromolecules, macromolecular complexes, cells, cellular components or tissues, or biogeochemistry of soils and soil components. Concepts responsive to this announcement include tools or instruments with specific value to BER targets of interest. Examples include but are not limited to sample preparation, handling, positioning, or detection; robotics or other automation approaches; beam focus or alignment; and tools that aid correlative approaches.

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 C59-13, "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

References:

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C59-15. BIOIMAGING TECHNOLOGIES FOR BIOLOGICAL SYSTEMS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I 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 terrestrial 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. The scope and priorities for BER supported biological research applications of bioimaging are described here: BER. 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. Automation must include aspects of instrumentation control, image acquisition, and data storage, and might also include automated data analysis. Automated systems that characterize multiple metabolic or phenotypic transformations and should measure more than one parameter and enable characterization of the relationship among parameters. The system should provide the integrative systems-level data needed to gain a more predictive understanding of complex biological processes relevant to BER. Systems should have a detailed intention for utility in solving a well described biological problem within the scope of the mission of BER. Initial technical development should be coupled to intended biological objectives and plans for technical and biological validation should be clearly described.

The instrumentation and devices to be developed for imaging biological systems will have high likelihood to enable an understanding of 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 C59-13 "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 C59-14, "ENABLING TOOLS FOR MOLECULAR STRUCTURE OR MORPHOLOGICAL CHARACTERIZATION OF BIOLOGICAL AND BIOGEOCHEMICAL INTERACTIONS WITHIN OR AMONG MICROBES, PLANTS, MINERALS, SOILS."

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. Measuring extracellular environmental characteristics including physical and chemical parameters in plants, soil-based rhizosphere communities, or synthetic model systems of microbe communities would also be of interest. Imaging in 2 or 3 dimensions is emphasized while time varying measurements are desirable but not necessary in early-stage development. Networks of quantum-enabled sensors that provide discontinuous but expansive environmental maps of measurements might also be considered if spatial or temporal resolution are appropriate to the biological or environmental problem to be addressed.

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

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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. Quantum sensor signal readout could be optical or other non-optical methods including electromagnetic or particle detection.

This subtopic for applications 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. Investigations at a larger scale including rhizosphere or whole plant responses to changing environments.

This subtopic for applications 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.
- Quantum-enabled sensors of selective biomolecules, metabolites, or physical and chemical environments either within or outside of cells and microbes.

EXCLUSIONS/RESTRICTIONS:

- 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 application, 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:

1. DOE, 2023, "*Biomolecular Characterization and Imaging Science Program*": 2023 Principal Investigator Meeting Proceedings, https://www.genomicscience.energy.gov/wp-content/uploads/2024/01/BCIS_PI_2023.pdf (June 25, 2024)
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3. Subcommittee On Quantum Information Science Committee On Science Of The National Science & Technology Council, 2022, "*Bringing Quantum Sensors to Fruition*", https://www.quantum.gov/wp-content/uploads/2022/03/BringingQuantumSensorstoFruition.pdf (June 26, 2024)

C59-16. DELIVERY TECHNOLOGIES FOR GENETIC ENGINEERING BIOENERGY CROPS

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

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Genetic engineering is essential to accelerate breeding efforts and to improve traits in ways unachievable by classical breeding. In bioenergy and biomass crops, traits of interest could include tolerance to abiotic or biotic stress, or end-use applications for biofuels and bioproducts to offset reliance on fossil resources (1- 3). A key challenge for the implementation of genetic engineering is transformation, the process of introducing DNA or protein into plant cells and regenerating engineered plants (4-6). This topic seeks to support new methods to engineer the genomes of bioenergy crop plants. Current methods to transform bioenergy crops are often time-consuming, technically challenging, and germplasm dependent, hindering the pace of development of bioenergy crops with improved traits (1; 7-10). Strategies to simplify and shorten the transformation process, develop cultivar independent protocols, and perform genetic modification without DNA integration are all needed (4-6; 11). One opportunity to address these limitations is to improve the delivery of nucleic acids and/or proteins into plant cells.

a. Improved Delivery Technologies

The objective of this subtopic is to support the development and commercialization of new technologies that deliver nucleic acids and/or protein into cells to facilitate the development of engineered bioenergy crop plants (including, but not limited to sorghum, energy cane, Miscanthus, switchgrass, Populus, Camelina, pennycress). Applications should clearly state how the technology will ease use and/or overcome obstacles associated with current delivery technologies used in bioenergy crops. Qualifying technologies include but are not limited to tools that simplify current protocols, reduce, or eliminate time in tissue culture, or facilitate gene editing without incorporation of foreign DNA. Phase I applications should focus on design, development, and optimization at the lab scale. It is highly recommended that applicants discuss their technology with the program contact to ensure fit prior to applying.

Questions – Contact: Kari Perez, Kari.Perez@science.doe.gov

b. Other

In addition to the subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above. It is highly recommended that applicants discuss their technology with the program contact to ensure fit prior to applying.

Questions – Contact: Kari Perez, Kari.Perez@science.doe.gov

References:

1. Nelson, R.S., et al., 2017, "*Development and use of a switchgrass (Panicum virgatum L.) transformation pipeline by the BioEnergy Science Center to evaluate plants for reduced cell wall recalcitrance*", Biotechnol Biofuels, Biotechnology for Biofuels and Bioproducts, 10:309. https://doi.org/10.1186/s13068-017-0991-x (June 24, 2024)
2. Hamdan, M.F., et al.,2022, "*Genome Editing for Sustainable Crop Improvement and Mitigation of Biotic and Abiotic Stresses*", Plants, 11:2625. https://doi.org/10.3390/plants11192625 (June 26, 2024)
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11. Son, S. and Park, S.R., 2022, "*Challenges Facing CRISPR/Cas9-Based Genome Editing in Plants*", Front. Plant Sci., 13:902413, https://doi.org/10.3389/fpls.2022.902413 (June 23, 2023)

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PROGRAM AREA OVERVIEW: OFFICE OF FUSION ENERGY SCIENCES

FES's mission is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. In addition, the FES mission includes advancing the basic research needed to solve fundamental science and technology gaps towards the development of fusion power as a clean energy source in the U.S using diverse set of tools and strategic approaches. This approach includes fulfilling the fusion energy mission by a shift in the balance of research toward the Long-Range Plan (LRP) Fusion Materials and Technology (FM&T) gaps, which connects the three science drivers: Sustain a Burning Plasma, Engineer for Extreme Conditions, and Harness Fusion Energy.

Once developed, fusion will provide a clean energy source well-suited for on-demand, dispatchable electricity production, supplementing intermittent renewables and fission. Energy from fusion will be carbon-free, inherently safe, with a virtually limitless fuel supply, and without the production of long-lived radioactive waste. Among the priorities of the program is to address the science and technology needs for the design basis of a Fusion Pilot Plant (FPP). To accelerate this move to a fusion based clean energy source, the administration "is developing a bold decadal vision to accelerate fusion – a clean energy technology that uses the same reaction that powers the Sun and stars". In addition, the Fusion Energy Strategy 2024 describes a three-pillared strategy to advance fusion energy via (1) Resolving the scientific and technological gaps to a fusion pilot plant, (2) Paving the way for commercial fusion deployment, and (3) Cultivating and expanding partnerships.

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

In addition to its fusion energy mission, FES also supports discovery plasma science, which is focused on research at the frontiers of basic and low temperature plasma science (with applications to microelectronics) and high-energy-density laboratory plasmas.

Finally, FES invests in transformational technologies such as artificial intelligence and machine learning (AI/ML), fundamental science to transform advanced manufacturing, and quantum information science (QIS), that have the potential to accelerate progress in several mission areas.

The following topics are restricted to advanced technologies and materials for fusion energy systems, fusion nuclear science, select technologies relevant to magnetically confined plasma, low temperature plasmas, and cross-cutting fusion needs.

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

C59-17. FUSION MATERIALS AND INTERNAL COMPONENTS

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

Fusion materials and structures must function for extended lifetimes in a uniquely hostile environment that includes a combination of high temperatures, high stresses, reactive chemicals, and intensely damaging radiation. The goal of this program is to establish the feasibility of designing, constructing and operating a fusion power plant with materials and components that meet demanding objectives for safety, performance, economics, and environmental impact.

Grant applications are sought in the following areas:

a. Precision Engineering Using Advanced or Additive Manufacturing.

There is an opportunity in advanced and additive manufacturing (A&AM) to build components in fusion that have complicated internal structures (e.g., waveguides and fusion plant cooling channels). A&AM has the potential for a number of material benefits, such as the production of stronger structures due to the annealing process or grain control. Such manufacturing could remove the need for brazing and welding resulting in a smaller chance of structural failure. In addition, A&AM has the potential to allow for lower production time, increased efficiency in logistics, and utilizing a smaller amount of energy as opposed to established methods of manufacturing.

Applicants must demonstrate what regime (fusion nuclear environment) that the material would be exposed to and how it would be able to withstand it in comparison to conventional materials. Beyond the expected R&D required to develop materials for these components, forethought into expected waste produced and mitigation strategies, scaling costs for manufacturing, and standards for QA/QC is highly encouraged.

Questions - Contact: John Echols, john.echols@science.doe.gov

b. Other

In addition to the specific subtopics listed above, we invite applications that address aspects of fusion materials and internal components science not aligned to the above subtopic. Applications that do not clearly explain how their proposed work is relevant to fusion may be declined without review.

Questions – Contact: John Echols, john.echols@science.doe.gov

C59-18. SUPERCONDUCTING MAGNETS

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

Magnets are the primary machine core cost driver for magnetic fusion devices. Fusion pilot plant (FPP) concepts and supporting magnet technologies must be developed in parallel to meet aggressive U.S. fusion power program schedules and beyond to a first of a kind plant. Alongside the public program, the SBIR/STTR program can help support the technology development required to meet this schedule. Below is the topic of interest to the FES:

a. Radiation-Resistant Insulators

Radiation-resistant electrical insulators that exhibit low gas generation and retention of mechanical strength under radiation, less expensive resins and insulation systems with high bond and higher strength and flexibility in shear environments.

Questions – Contact: John Echols, john.echols@science.doe.gov

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b. Quench Detection Technologies

In order to quickly progress this fiber optic quench detection technology at the scale (100s of km) and timeline to commercialize fusion energy in the next decade, industry maturity and economies of scale are needed in the following topics: radiation hardened fiber development with low microbend loss susceptibility, FBG (fiber Bragg grating) inscription technology capable of inscribing 1000's of FBGs per fiber on radiation resistant fiber coating, development of alternative fiber recoating and splicing technology for multiple fibers at a time with radiation resistant coating that is reliable and quick.

Needed are optical interrogator hardware that can be manufactured at low cost and with high throughput to accommodate hundreds of fiber channels, each with high dynamic range capability. Factors such as radiation-induced attenuation (RIA) and other insertion loss mechanisms further complicate this requirement, necessitating interrogators that can handle high dynamic ranges while maintaining narrow spectral wavelength resolution, sampling rates greater than 100 Hz, and high laser output power.

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

c. Other

In addition to the specific subtopics listed above, we invite applications that address aspects of superconducting magnets not aligned to the above subtopic. Applications that do not clearly explain how their proposed work is relevant to fusion may be declined without review.

Questions – Contact Josh King, josh.king@science.doe.gov

C59-19. FUSION NUCLEAR SCIENCE

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

Fusion nuclear science encompasses subcomponent technologies and processes required to fuel and maintain balance of plant for a fusion energy system. These subsystems include but are not limited to the fusion breeding blanket, radiation transport and nuclear analysis, fusion fuel cycle, fuel separation, exhaust processing, and fuel accountability. Areas listed below are of particular interest:

a. Fusion Fuel Cycle

A safe, efficient, and reliable fuel cycle is important for the commercialization of fusion energy. Many fusion concepts under development will require a robust deuterium-tritium (D-T) fuel cycle, and alternative fusion fuel cycles also have isotope processing needs. The requirements of the associated fueling systems will require the evolution of fuel handling technologies, in particular regarding tritium, to assure reliable and sustained operations. Public tritium processing and handling systems have been developed for fusion (JET, ITER, TFTR) and for waste processing (e.g. Candu Reactors). FES is interested in innovating the subcomponent to support fusion relevant fuel cycle operations (operating effectively continuous, with circulating flow rates on the order of kilograms of tritium per day, and total tritium inventories on the order of hundreds of grams.). FES encourages fuel cycle technology development performed with protium and deuterium, but validation in a relevant environment will require testing with tritium [1]. Companies are encouraged to work with domestic and international public or private testing facilities. Below are particular objectives each fuel cycle subcomponent must consider:

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- Develop techno-economic studies to evaluate the various fusion fuel cycle concepts and key performance metrics, including requirements for reliability, availability, maintainability, and inspectability (RAMI).
- Develop exhaust processing and detritiation techniques that will enable fusion energy production to scale economically. Explore methods for regeneration or recycling of fusion fuel cycle materials such as getters, and adsorbents as well as advancing water detritiation systems.
- Perform risk and budget/planning assessments associated with technology deployment. These assessments would address workforce training needs, safety procedures, technology readiness assessment levels for technology deployments, supply chain, and other relevant areas.
- Assess how to optimally implement nonproliferation, export control, waste disposal, accident scenarios, and community engagement for the fusion fuel cycle.

[1] Fusion Fuel Cycles Research Objectives: Results from the 2023 Fusion Fuel Cycles Workshop. EPRI, Palo Alto, CA: 2024. 3002029371. https://lnkd.in/euA38B8m

Questions - Contact: Guinivere Shaw, guinevere.shaw@science.doe.gov

b. Other

In addition to the specific subtopics listed above, we invite applications that address aspects of fusion nuclear science not aligned to the above subtopic. Applications that do not clearly explain how their proposed work is relevant to fusion may be declined without review.

Questions - Contact: Guinivere Shaw, guinevere.shaw@science.doe.gov

C59-20. LOW TEMPERATURE PLASMAS FOR BIOMEDICAL APPLICATIONS

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

Low-temperature plasmas (LTPs) have continued to play a major role in breathtaking technological advances, ranging from the development of cost-effective lighting to advanced microelectronics, that have improved the quality of our lives in many ways. LTPs are continuing to enable technological advances in new fields, such as deactivation of antibiotic resistant bacteria, disinfection of viruses, and cancer therapy in plasma medicine. All of these advances are enabled by the unique properties of low-temperature, non-equilibrium plasma and the chemistry they drive. Building upon fundamental plasma science, further developments are sought in plasma sources, plasma-surface interactions, and plasma control science that can enable new plasma technologies, marketable product, or impact in other areas or disciplines leading to even greater societal benefit. The focus of this topic is utilizing fundamental plasma science knowledge and turning it into new applications.

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

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All low-temperature plasma applications must have a strong commercialization potential. Grant applications are sought in the specific areas listed under the following subtopics:

a. LTP Science and Technology for Biomedical Applications

This subtopic is focused on improving our current understanding and scientific knowledge in the area of plasma chemistry, plasma-liquid and plasma-biomatter interactions related to plasma medicine. Current challenges include: development of efficient and effective plasma sources, discharges, and/or jets for biomedical applications; improving the control of plasma produced reactive species, charged particles, photons, and fields and understanding of how these agents impact or destroy cancer cells, antibiotic resistant bacteria, COVID-19 viruses, and/or wound healing.

Note: The two subtopics: (i) LTP Science and Technology for Biomedical Applications including topics in plasma-based water treatment, sterilization, food sanitation, and agriculture (nitrogen fixation or fertilizer) and (ii) LTP Science and Engineering for Microelectronics and Nanotechnology including topics in renewable energy applications are planned to be rotated biennially (once every two years).

Questions – Contact: Nirmol Podder, Nirmol.Podder@science.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications that can enhance the understanding of other emerging areas of plasma applications, including plasma-based water treatment, sterilization, food sanitation, and/or agriculture (nitrogen fixation or fertilizer).

Questions – Contact: Nirmol Podder, Nirmol.Podder@science.doe.gov

References:

1. National Academies of Sciences, Engineering, and Medicine, 2020, "*Plasma Science: Enabling Technology, Sustainability, Security, and Exploration*", Washington, DC: The National Academies Press, https://doi.org/10.17226/25802 (June 26, 2024)
2. American Physical Society Division of Plasma Physics Community Planning, 2019,Process: "*A Community Plan for Fusion Energy and Discovery Plasma Sciences*", https://drive.google.com/file/d/1w0TKL_Jn0tKUBgUc8RC1s5fIOViH5pRK/view (June 26, 2024)
3. Fusion Energy Sciences Advisory Committee , 2020, "*Powering the Future Fusion & Plasmas*", A Report of the Fusion Energy Sciences Advisory Committee, https://science.osti.gov/-/media/fes/fesac/pdf/2020/202012/FESAC_Report_2020_Powering_the_Future.pdf (June 26, 2024
4. U.S. Department of Energy Office of Fusion Energy Science, 2016, "*Plasma: At The Frontier of Scientific Discovery*", Report of the Panel on Frontiers of Plasma Science, chapter 5, pp. 85-96, https://science.osti.gov/-/media/fes/pdf/program-news/Frontiers_of_Plasma_Science_Final_Report.pdf?la=en&hash=85B22EBF1CF773FFC969622524D603D755881999 (June 26, 2024)

C59-21. PLASMA CONTROL FOR FUSION POWER PLANTS

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

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Commercial and research fusion energy systems require advanced plasma control systems to discover and sustain optimized burning plasma states, ensure the safe operation of fusion technology, and to protect capital investments during facility operations.

a. Autonomous Plasma Control Systems

This subtopic seeks the development of commercial autonomous plasma control systems (APCS) for fusion energy concepts based on all plasma confinement approaches. A proposed APCS should be capable of creating, sustaining, optimizing, and safely terminating plasma discharges with minimal human operator intervention. Applicants should propose to develop and commercialize both system components and integrated systems involving real-time control hardware and software. APCS system capabilities of interest include but are not limited to: automated processing and visualization of real-time diagnostic and sensor data; development and deployment of data- and physics-based models; automated plasma state inference; machine learning methods for identification and labeling of normal and off-normal events and event chains; real-time prediction of future plasma trajectories; predictive control methods; shared actuator strategies, plasma stability and controllability monitoring; use of artificial intelligence for guiding adaptive control strategies, and novel machine-human interfaces that support facility operation. Applications that propose research utilizing only high-performance computing resources, or focused entirely on artificial intelligence and machine learning without any real-time deployment of the associated capabilities are encouraged to apply to the Artificial Intelligence/ Machine Learning subtopic C59-22c.

Questions – Contact: Matthew Lanctot, matthew.lanctot@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: Matthew Lanctot, matthew.lanctot@science.doe.gov

C59-22. CROSS-CUTTING /ENABLING TECHNOLOGIES

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

Advancing fusion energy will require development of a variety of technologies that do not necessarily align to the other fusion topics listed, and that may address multiple topics or prove to be broadly enabling for multiple fusion approaches.

a. Power Electronics/Gyrotrons/Heating

This subtopic seeks solutions to power electronics and plasma heating needs for fusion. Technologies to enable more efficient gyrotrons (vacuum electron devices capable of generating high-power, high-frequency radiation) and/or gyrotrons with longer lifetimes are of specific interest, as are approaches that enable lower costs and increased reliability and lifetime. Applicants should take care to explain how their proposed work (specific activities, frequency, power, target efficiency) aligns to specific fusion heating needs and offers potential to improve on specific state-of-the-art performance. Applicants that do not clearly link the proposed work to a specific fusion-relevant need may be declined without review.

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Questions - Contact: Colleen Nehl, colleen.nehl@science.doe.gov

b. High Performance Computing

This subtopic seeks to advance the development and application of large-scale fusion-relevant simulation codes that require the use of supercomputing resources to model complex behavior. Efforts that are eligible to apply include but are not limited to: edge computing that communicates with DOE clusters in part of an Integrated Research Infrastructure1 ecosystem, codes that offer predictive capabilities, and codes that reconstruct plasma discharges to further understand the underlying physical mechanisms underway. Work that requires the use of massive quantities of data and/or novel algorithms to predict plasma performance should seek support under the Machine Learning subtopic.

Questions - Contact: Michael Halfmoon, michael.halfmoon@science.doe.gov

c. Artificial Intelligence/ Machine Learning

This subtopic seeks to support the application of novel algorithms and large datasets to construct predictive models for plasma performance. Efforts include but are not limited to: foundation models for generative AI solutions to fusion-relevant problems, large-scale data curation and repository efforts, physics-informed neural networks for predictive modeling capabilities, real-time data analysis for stability prediction with AI algorithm support. Efforts that are focused on entirely automated systems for plasma control should seek support under the Autonomous Plasma Control System topic (C59-21a). Efforts that require the use of DOE supercomputing clusters for HPC codes should seek support under the High Performance Computing subtopic.

Questions - Contact: Michael Halfmoon, michael.halfmoon@science.doe.gov

d. Vacuum Pumps

This subtopic seeks development and improvements to vacuum pumps suitable for fusion environments, including considerations specific to fusion-relevant fuels, including separation techniques. Topics of interest include, but are not limited to separation membranes, pump oil treatments, pump designs that are specialized to handle corrosive and/or radioactive gases. Vacuum pumps for fusion technology must guarantee compatibility with tritium, nuclear radiation, magnetic fields, shock, and air inrush accidents, without contamination of pumped gases. A leak-tight operation with metal-based sealings alone must also be ensured. These pumps must provide a high pumping speed for light gases like hydrogen, tritium, and deuterium, guaranteeing a base pressure of < 1x10-8 mbar. When used to recycle helium in cryostats, the pumps must move huge quantities of helium in the 1x10-5 pressure range. If applicants do not clearly link their proposed work to a specific fusion-relevant needs, their application may be declined without review.

Questions - Contact: Guinivere Shaw, guinevere.shaw@science.doe.gov

e. Other

In addition to the specific subtopics listed above, we invite applications that address aspects of fusion technology and fusion-relevant R&D not otherwise aligned to the above subtopics. Applications that do not clearly explain how their proposed work is relevant to fusion may be declined without review.

Questions - Contact: Colleen Nehl, colleen.nehl@science.doe.gov

References – Subtopic b:

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1. DOE Office of Science, 2023, "*Integrated Research Infrastructure Architecture Blueprint Activity*", https://www.osti.gov/servlets/purl/1984466/ (June 26, 2024)

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PROGRAM AREA OVERVIEW: OFFICE OF HIGH ENERGY PHYSICS

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

The DOE HEP program supports research in three discovery frontiers, namely, the energy frontier, the intensity frontier, and the cosmic frontier. Experimental research in HEP is largely performed by university and national laboratory scientists, using particle accelerators as well as telescopes and underground detectors located at major facilities in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago, IL. The Department also has a significant role in the Large Hadron Collider (LHC) at the CERN laboratory in Switzerland. The Fermilab complex includes the Main Injector (which formerly fed the now dormant Tevatron ring), which is used to create high-energy particle beams for physics experiments, including the world's most intense neutrino beam. The Main Injector is undergoing upgrades to support the operation of Fermilab's present and planned suite of neutrino and muon experiments at the intensity frontier. Another Fermilab upgrade project called PIP-II (Proton Improvement Plan II) will greatly increase the intensity of proton beams sent to the Main Injector. The SLAC National Accelerator Laboratory and the Lawrence Berkeley National Laboratory are involved in the design of state-of-the-art accelerators and related facilities for use in high-energy physics, condensed matter research, and related fields. SLAC facilities include the two-kilometer-long Stanford Linear Accelerator capable of generating high energy, high intensity electron beams. The first kilometer of the linear accelerator is used for the Facility for Advanced Accelerator Experimental Tests (FACET-II). At Argonne National Laboratory resides the Argonne Wakefield Accelerator (AWA) facility, which houses two test electron accelerators, one for 15 MeV electrons, and the other for 70 MeV electrons. Experiments focus on two-beam and collinear wakefield acceleration as well as tests of novel accelerator structures and beam-line components. Brookhaven National Laboratory operates the Accelerator Test Facility, which supports accelerator science and technology demonstrations with electron and laser beams. While much progress has been made during the past five decades in our understanding of particle physics, future progress depends on the availability of new state-of-the-art technology for accelerators and detectors.

As stewards of accelerator technology for the nation, HEP also supports development of new concepts and capabilities that further scientific and commercial needs beyond the discovery science mission. Artificial Intelligence/Machine Learning science and technology is another rapidly-developing area that both benefits from expertise in the HEP community and offers novel approaches for extending HEP science. The DOE SBIR program provides a focused opportunity and mechanism for small businesses to contribute new ideas and new technologies to the pool of knowledge and technical capabilities required for continued progress in HEP research, and to turn these novel ideas and technologies into new business ventures.

Grant applications must be informed by the state of the art in High Energy 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 High Energy Physics program. DOE also expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry.

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

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C59-23. ADVANCED CONCEPTS AND TECHNOLOGY FOR PARTICLE ACCELERATORS

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

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

In many cases the technology sought is closely tied to a specific machine concept which sets the specifications (and tolerances) for the technology. Applicants are strongly encouraged to review the references provided. Applications to subtopics specifically associated with a machine concept that do not closely adhere to the specifications of the machine will be considered non- responsive. For subtopics that are not machine-specific, applicants are strongly advised to understand the state-of- the-art and to clearly describe in the application what quantitative advances in the technology will result.

Grant applications are sought only in the following subtopics:

a. Graphical User-Interfaces for Accelerator Modeling

The HEP program supports theoretical and experimental research in elementary particle physics and fundamental accelerator science and technology [1]. Particle accelerator and beamline modeling for both conventional and advanced accelerator concepts has undergone major advances with the advent of the world's first Exascale supercomputer in the US DOE (Frontier at OLCF), GPU-accelerated computing and novel algorithms [2]. Yet, advanced modeling tools could have a significantly wider impact in research and industry if they were accessible via modern, intuitive design-centric interfaces and were able to be coupled easily to control systems in experiments. Addressing these points, applications are sought after that can develop extensible, graphical user interfaces, which can leverage community standards in modeling for simulation control and data [1-3] and control asynchronous particle accelerator modeling workflows on remote computing hardware (edge computing close to experiments, on clusters, cloud, and/or HPC).

Questions – Contact: Derun Li, Derun.Li@science.doe.gov

b. Digital Twin for HEP Accelerator Beam Test Facilities

Applications are sought for the creation of a digital twin of one or more DOE HEP accelerator beam test facilities, as outlined in the 2022 ABP Roadmap [1]. The digital twin should serve several key purposes. Primarily, it should provide an accessible platform for both existing and potential users of the facility to intuitively explore ideas and design experiments. Secondly, this initiative presents an opportunity to experiment with advanced control system algorithms for both specific subsystems and the facility. Special focus should be given to automated tuning, particularly in situations where the machine exhibits drift. Lastly, it is anticipated that the digital twin will incorporate multiple community modeling codes for various subsystems. While a variety of approaches can be considered, there should be a particular emphasis on AI/ML representations such as surrogate models and model-free representations.

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Questions – Contact: Derun Li, Derun.Li@science.doe.gov

c. Non-Destructive Electron Beam Position Monitors

Advancements in RF-driven and plasma-driven accelerators have resulted in the production of femtosecond-duration electron beams in an environment potentially subject to strong background EMP radiation. To integrate active stabilization, machine learning and artificial intelligence, as well as shot-tagged correlation studies, it is desirable to develop shot-correlated non-perturbative diagnostics for the electron beam position and pointing angle. Challenges related to the shortness of the electron beam and EMP-noise chamber environment have frustrated conventional BPMs (beam position monitors). Applications are sought for either improvements to BPMs (cavity BPMs), or for novel technologies such as fiber-integrated electro-optic sampling components and/or near-field imaging of aperture-based coherent diffraction radiation. These diagnostics should provide a path for robust, reliable, and operation-friendly passive centroid and pointing monitors for high-current ultra-short electron beams in noisy environments.

Questions – Contact: Derun Li, Derun.Li@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: Derun Li, Derun.Li@science.doe.gov

References - Subtopic a:

1. US DOE HEP General Accelerator R&D (GARD) Program, 2023, Accelerator and Beam Physics Roadmap, https://science.osti.gov/hep/-/media/hep/pdf/2022/ABP_Roadmap_2023_final.pdf (June 29, 2023)
2. Elvira, V.D., et al., 2022, The Future of High Energy Physics Software and Computing, Report of the 2021 US Community Study on the Future of Particle Physics, https://arxiv.org/abs/2210.05822 (June 26, 2023)
3. The Beam and Accelerator Modeling Interest Group (BAMIG), 2022, Snowmass21 Accelerator Modeling Community White Paper, Cornell University, https://arxiv.org/abs/2203.08335 (June 26, 2023)

References - Subtopic b:

1. US DOE HEP General Accelerator R&D (GARD) Program, 2023, Accelerator and Beam Physics Roadmap, https://science.osti.gov/hep/-/media/hep/pdf/2022/ABP_Roadmap_2023_final.pdf (June 29, 2023)

C59-24. RADIO FREQUENCY ACCELERATOR TECHNOLOGY

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

Radio frequency (RF) technology is a key technology common to all high energy accelerators. RF sources with improved efficiency and accelerating structures with increased accelerating gradient are important for keeping the cost down for future machines. DOE-HEP seeks advances directly relevant to HEP applications and new concepts and capabilities that further scientific and commercial needs beyond HEP's discovery science mission.

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

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

a. Low-Cost Radio Frequency Power Sources for Accelerator Application

Low cost, highly efficient RF power sources are needed to power accelerators. Achieving power efficiencies of 50-70% or better (depending on the application) and decreasing capital costs below $2/Watt of average power output is essential. For accelerator applications, RF sources must phase lock stably (<1 degree RMS phase noise) to an external reference and have excellent output power stability (<1% RMS output power variation) and device lifetime must exceed 10,000 operating hours.

Applications for either vacuum electronics devices or solid-state power amplifiers are sought. Please note that the R&D priority varies by type of tube. Priority will be given to applications that develop RF power sources operating at frequencies that are in widespread use at the large Office of Science accelerators.

Five major types of RF power sources are sought. For each RF source type, the principal R&D challenges have been *marked* and meeting the relevant specifications should be the focus of proposed work.

1) Short-pulse (microsecond) L-band or S-band, low duty factor (0.1%), *very high efficiency (>70%), low cost (<$2 per average Watt)* RF sources, with beam operating voltages below 100 kV preferred, and peak output power of 10 MW (L-band) to 50 MW (S-band);
2) Short-pulse (microsecond) C-band or X-band, low duty factor (>0.1%), *high efficiency (>50%) RF sources*, with peak output power of >50 MW, moderate bandwidth (-3dB BW >0.5%) and *capable of high repetition rate (>>1 kHz) operation*;
3) Long-pulse (millisecond) UHF or L-band, high duty factor (>5%), *very high efficiency (>70%), low cost (<$2 per average Watt)* RF sources, with beam operating voltages below 100 kV preferred (if a vacuum electronic device), and peak output power of >100 kW;
4) CW UHF or L-band, very high duty factor (100%), *very high efficiency (>70%), low cost (<$2 per average Watt)* RF sources, with beam operating voltages (if a vacuum electronic device) below 100 kV preferred, and peak power output of >20 kW;
5) Short-pulse (microsecond) C-band or X-band, low duty factor (0.1%), *high efficiency (>50%)* solid-state power amplifiers, with peak output power of >5 kW, with an early production cost of <$10/(peak Watt) and a *volume production cost of <2$(peak Watt)*.

Background Information about each RF Source Type follows:

1) This type of RF source is typical of warm linear accelerators. [1,2,3]

2) This type of RF source is typical of high energy physics accelerators [1] next-generation compact x-ray free electron laser (XFEL) facilities [4] and relativistic, ultra-fast electron diffraction facilities (MeV-UED) [5], [6]. Current sources, such as those used at SACLA (Japan), SwissFEL and CERF-NM [7] preclude the use of C-Band technology to its fullest capability.

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X-band accelerating structures have been demonstrated to work above 300 MV/m [11] using ultra-short RF pulses, a gradient that can substantially reduce the size of high energy accelerators. This demonstration was done in a two-beam accelerator scheme using a Power Extraction and Transfer Structure (PETS, a beam driven source) [12]. With available klystrons, RF pulses are typically > 100 ns and gradients are ~100 MV/m [13].

In order to fully realize the potential for these high frequency, high gradient accelerating structures, an ultra-high-power source with ultra-short pulses is required. A possible source could be based on a high-bandwidth klystron (the subject of this topic) [14] and an active, high-bandwidth, RF pulse compressor (the subject of a future SBIR topic) [15].

3) The very high gradient accelerators made possible could be used for High Energy Physics, Basic Energy Sciences, and other basic research in material science. C-Band MeV-UED facilities would allow for the study of non-equilibrium dynamic processes in materials at sub- angstrom scales and femtosecond time resolution. Potential users of such a capability are interested in “burst mode” operation, for instance repetition rates on the order of 1 MHz while still maintaining an overall duty factor of ~0.01%. Compact C-Band XFELs that can provide multiple pulses (10s – 100s) of high photon energy (~42 keV) x-ray pulses with variable separation from 100 picoseconds to 100 microseconds would enable dynamic imaging of dense, high Z materials. However, such a system would require a new power source that could meet the desired pulse structure.

4) This type of RF source is typical of superconducting linear accelerators. [1,2,3]

5) This type of RF source is typical of storage ring accelerators, CW linear accelerators, and industrial accelerators. [1,2,3]

6) This type of RF source is typically used as a TWT replacement for driving short-pulse klystrons but also finds uses driving beam diagnostics and beam manipulation in compact linacs. For example, [8] describes the use of an X-band cavity to deflect a high energy electron beam (14 GeV) to measure its longitudinal profile. Solid state RF sources are sought for beam diagnostics and manipulation (as TWT replacements) at much lower electron beam energies (~MeV) in compact accelerators based on C- and X-band. Peak or continuous wave (CW) power is needed at > 5 kW for adequate deflection of these beams, higher power than what is currently available from solid state amplifiers.

   A solid-state narrowband amplifier is required (< 100 MHz) at high power (> 5 kW peak power or CW) in the C and X bands. Cost should target $10/W with a path forward for volume production costs of a few $/W.

   Compact Linacs are used in industry and medicine [9]. RF power sources are additionally used in radar and space telecommunications [10].

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

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

b. New Tunable Superconducting Cavities for Proton Accelerators

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New tunable SRF cavity designs for operation with high current beams. The tuning range is to be up to 10^{-2}. The cavity should provide efficient high-order mode extraction while not sacrificing good SRF performance. The cavities may be used in present and future accelerators – Electron-Ion Collider at BNL, PIP-II at Fermilab. For example, the present RF system of the Fermilab Main Injector contains 18 room-temperature ferrite-loaded cavities. The PIP-II plan suggests high beam power (>2 MW) which in turn requires additional cavities. Grant applications are sought for development of the new superconducting tunable cavities. 5-6 SRF cavities will be enough to achieve the required beam parameters.

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

c. Auxiliary Components and Instrumentation for SRF Cavities

Grant applications are sought to develop:

1) Further development of the new RF windows made of conductive ceramics providing low RF loss together with DC conductivity, that prevents the window breakdown under the beam.

2) New cost-efficient and improved reliability designs of high-power and low-power components - input couplers, circulators, windows, tuners, etc., in the frequency range of 325 MHz to 1.3 GHz.

3) New and improved methods for cavity diagnostics in a cryomodule that would aid to preserving the high performance achieved by SRF cavities during vertical tests throughout the SRF cryomodule assembly, commissioning and operation, including in situ Q0 measurements, inexpensive sensors for residual magnetic field measurements at cryogenic temperatures, novel sensors for helium pressure, flow, and level based on fiber optics or other technologies, vibration sensors operating in a cryogenic environment, distributed radiation and dark current/field emission sensors using fiber optics at cryogenic temperatures.

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

References - Subtopic a:

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11. Jiahang Shao et al., "Demonstration of Gradient Above 300 MV/m in Short Pulse Regime Using an X-Band Single-Cell Structure", in Proc. IPAC 2022 https://jacow.org/ipac2022/papers/froxsp2.pdf
12. Julian Picard et al., "Generation of 565 MW of X-band power using a metamaterial power extractor for structure-based wakefield acceleration" Phys. Rev. Accel. Beams 25, 051301 – Published 16 May 2022 https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.25.051301
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14. Xiancai Lin et al. "X-band two-stage rf pulse compression system with correction cavity chain" Phys. Rev. Accel. Beams 25, 120401, 13 December 2022, https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.25.120401
15. O. A. Ivanov et al. "Active Microwave Pulse Compressor Using an Electron-Beam Triggered Switch" Phys. Rev. Lett. 110, 115002 – Published 12 March 2013, https://doi.org/10.1103/PhysRevLett.110.115002

C59-25. LASER TECHNOLOGY R&D FOR ACCELERATORS

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

Lasers are used or proposed for use in many areas of accelerator applications: as drivers for novel accelerator concepts for future colliders; in the generation, manipulation, and x-ray seeding of electron beams; in the generation of electromagnetic radiation ranging from THz to gamma rays; and in the generation of neutron, proton, and light ion beams. In many cases ultrafast lasers with pulse lengths well below a picosecond are required, with excellent stability, reliability, and beam quality. With applications demanding ever higher fluxes of particles and radiation, the driving laser technology must also increase in repetition rate—and hence average power—to meet the demand. Please note that proposals submitted in this topic should clearly articulate the relevance of the proposed R&D to HEP's mission.

This topic area is aimed at developing suppliers for technologies for (1) ultrafast lasers capable of high average power (kilowatt-class) operation at high electrical-to-optical efficiency (e.g., >20%) needed for accelerator

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applications, and (2) high average power custom-pulse-structure lasers for proton and ion beam manipulation and diagnosis.

In category (1), accelerator applications of ultrafast lasers call for one of the following three basic specifications (details given in [16]):

	Type I: High-repetition rate	**Type II: High-average power**	**Type III: Few-cycle**
Pulse peak power	>1 kW	10 – 300 TW	1 – 10 TW
Wavelength	0.8 – 10 µm	0.5 – 10 µm	2 – 5 µm
Pulse Energy	n.c.	1 – 10 J	10 – 100 mJ
Pulse Length	n.c.	30 – 100 fs[1]	few-cycle
Repetition Rate	0.1 – 1 GHz	1 – 10 kHz	> 100 kHz
Average Power	10 – 100 W	1 – 100 kW	50 – 500 W
Energy Stability	<1%	<1%	<0.5%
Beam Quality	Strehl > 0.95	(Strehl > 0.95)[1]	Strehl > 0.95
Wall-plug Efficiency	n.c.	>10% for <10kW >20% for >10kW	n.c.
Pre-pulse contrast	n.c.	>10^5	n.c.
Time window for pre-pulse	n.c.	ns – ps	n.c.
Phase stability if CEP locked	< 100 mrad	Optional, < 300 mrad	< 100 mrad
Pointing stability	n.c.	< 0.1 µrad	n.c.
Bandwidth	n.c.	Transform-limited	n.c.

n.c. – not critical, can be freely determined from other specifications in the table
[1] requirement applies to lasers at 1-2 micron wavelength, with scaled requirements for longer wavelengths

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

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

a. Aperture-Scalable High Performance Diffraction Gratings

Diffraction gratings are employed in high energy laser systems in several ways, including pump wavelength stabilization, spectral beam combining, pulse compression, and near-field spatial filtering. These components are of critical importance in enabling high average power petawatt-class laser systems. Traditional surface-etched gratings, while aperture scalable, suffer from poor diffraction efficiency and high loss. Volumetric gratings deliver high diffraction efficiencies with excellent spectral and angular selectivity but suffer from poor uniformity when scaling to large apertures needed in high energy laser systems. Grant proposals are sought which will enable scaling of dispersive optical elements to large apertures (greater than 10 cm x 10 cm) while

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maintaining excellent uniformity (5% minimum, with >10% preferred), high diffraction efficiency (>99% in reflection mode or >95% in transmission mode at 1 micron, or >90% minimum in reflection mode at 10 microns), and high optical damage threshold (>0.5 J/cm^2 at 1 ps or >10 J/cm^2 at 1 ns). Proposals that include work to develop new grating substrate technologies (e.g., ceramics with or without embedded cooling) that are capable of very high average power operation (>1 kW average) are encouraged. Of particular interest are technologies which enable such improvements while reducing the cost of such components, possibly including manufacturing methods such as novel stitching techniques or innovations drawn from semiconductor manufacturing and etching techniques.

Further information can be found in [16] under Priority Research Direction 4 thrust 3 (page 50).

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

References:

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C59-26. HIGH FIELD SUPERCONDUCTING MAGNET TECHNOLOGY

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

Superconducting magnets are widely used in particle accelerators for beam steering and focusing. Advanced R&D is needed in support of this research in high-field superconductor and superconducting magnet technologies. This topic addresses only those superconducting magnet development technologies that support accelerators, storage rings, and charged particle beam transport systems and only those superconducting wire technologies that support long strand lengths suitable for winding magnets without splices. For referral to lab and university scientists in your area of interest contact: Ken Marken, ken.marken@science.doe.gov.

Grant applications are sought only in the following subtopics:

a. High-Field HTS Wire and Cable Technologies for Magnets

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Grant applications are sought to develop improved High Temperature Superconducting (HTS) wire for magnets that operate at or above 18 Tesla (T). Applications should address demonstration scale (>1 km lengths) and/or production scale (> 3 km continuous lengths) wire technologies. Current densities should be at least 400 amperes per square millimeter of strand cross-section (often called the engineering current density) at 20 T and 4.2 K temperature. Tooling and handling requirements restrict wire cross-sectional area to the range 0.4 to 2.0 square millimeters, with transverse dimension not less than 0.25 mm. Of specific interest are the HTS materials Bi2Sr2CaCu2O8 (Bi-2212) and (RE) Ba2Cu3O7 (ReBCO) that are engineered for high field magnet applications. All grant applications must result in wire technology that will be acceptable for accelerator magnets, including not only the operating conditions mentioned above, but also production of a sufficient amount of material (1 km minimum continuous length) for winding and testing cables and subscale coils.

New or improved wire or cable technologies must demonstrate at least one of the following criteria in comparison to present art:

- property improvement, such as higher current density at fields at or above 18 T;
- improved tolerance to property degradation as a function of applied strain;
- reduced transverse dimensions of the superconducting filaments (sometimes called the effective filament diameter), in particular to less than 30 micrometers at 1 mm wire diameter, with minimal concurrent reduction of the thermal conductivity of the stabilizer or strand critical current density;
- HTS cables supporting 10 to 30 kA currents with engineering current density above 600 A/mm^2, lower losses under changing transverse magnetic fields, and/or improved tolerance to transverse stress;
- significant cost reduction for equal performance in all regards, especially current density and length.

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

b. Cryogenic Power Electronics for Distributed Powering and Quench Protection of HTS and Hybrid Magnets

Powering and protection of high-field superconducting magnets are traditionally accomplished with current control and energy extraction systems operating at ambient temperature. These systems are costly, have low energy efficiency and put significant limitations on the powering and depowering profiles that can be executed. Recent advances in power electronics have enabled a new class of MOSFET devices that exhibit extremely low resistance in the “closed” state and allow for cryogenic operation. Implementation of these devices with superconducting magnets would significantly reduce cost and complexity of magnet powering infrastructure and enable novel capabilities such as independent current control for hybrid HTS/LTS magnet coils from a single power supply and generation of special AC current waveforms for clearing remnant magnetization or boosting protection through ac loss mechanisms.

Proposals are sought for practical implementation of viable cryogenic power electronics systems for superconducting magnets operating in the 2-5 Kelvin temperature range.

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

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C59-27. HIGH ENERGY PHYSICS ELECTRONICS

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

High Energy Physics experiments require advanced electronics and systems for the acquisition and processing of experimental data. As an example, high-priority future experiments in the DOE Office of High Energy Physics (HEP) portfolio need advances that can benefit from small business contributions. These experiments include potential upgrades to the High Luminosity Large Hadron Collider (HL-LHC) detectors currently under construction (see https://home.cern/science/accelerators/large-hadron-collider) or other potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., https://www.dunescience.org), next-generation direct searches for dark matter, and astrophysical surveys to understand dark energy, including cosmic microwave background experiments.

We seek small business industrial partners to advance the state of the art and/or increase cost effectiveness of electronics needed for the above experiments and for the wider HEP community. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. R&D seeking new technology will typically be in progress at DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific technology areas, the scientists involved are the best source of detailed information about requirements and

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relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists to develop germane applications. Clear and specific relevance to HEP programmatic needs is required and supporting letters from lab and university scientists are an excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov.

Grant applications are sought in the following subtopics:

a. Radiation-Hard Sensors and Engineered Substrates for Detectors at High Energy Colliders

Silicon detectors for high energy particle physics are currently based on hybrid technology, with separately fabricated diode strip or pixel sensors and bump-bonded Complementary Metal Oxide Semiconductor (CMOS) readout chips. As larger area detectors are required for tracking, and for new applications such as high-granularity calorimetry, new sensor concepts and lower manufacturing cost are needed. Sensors must withstand both ionizing and displacement damage radiation, and they must have fast signal collection and fast readout. Requirements for radiation tolerance depend on the distance from the interaction point, ranging from 0.1 to 3 Gigarad and 1E15 to 1E18 neutron-equivalent fluence depending on application.

Of interest are applications in the following focus areas:

- We seek monolithic CMOS-based sensors with moderate depth (5–20 micron) high resistivity substrates that can be fully depleted and can achieve charge collection times of 20 ns or less. Technologies of interest include deep n- and p-wells to avoid parasitic charge collection in CMOS circuitry and geometries with low-capacitance charge collection nodes. Structures with in-pixel signal processing, such as Monolithic Active Pixel Sensors (MAPS) and Skipper-in-CMOS, are of particular interest.
- We also seek low to moderate gain (×10–50) reach-through silicon avalanche diodes (LGADs) as a proposed sensor type to achieve ~10 ps time resolution for collider experiments. The current generation of reach-through diodes suffers from large fractional dead area at the edges of the pixel and only moderate radiation hardness. A moderately doped thin buried (~5 micron) layer replacing a reach- through implant can address some of these problems. We seek substrate fabrication technologies to improve the radiation hardness and stability of these devices by using graded epitaxy or wafer bonding to produce a buried and moderately doped (1E16) thin buried gain layer on a high resistivity substrate. We also seek techniques to arrange internal doping of detectors by multiple thick epitaxial layers or by other methods (e.g., deep ion implantation) to allow engineering of the internal fields and resulting pulse shape.
- Development of sensors fabricated in materials other than silicon and with enhanced performance was identified as a priority research direction in [1]. A promising direction is ultrafast sensors using Silicon Carbide (SiC), a large bandgap material for which industry is currently focused mainly on power electronics applications. For wide bandgap materials, we seek sources for thick (50–75 microns) epitaxially grown n-type layers with low doping concentration in the range 1E13 to 1E14, to serve as substrate materials for the development of ultrafast, radiation-hard sensors that can operate at room temperature or above (i.e., without cooling).

Diamond materials are not within the scope of this subtopic.

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

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b. Novel Interconnect Techniques and Integration

With the large channel counts and fine granularity of HEP detectors, there is an ever-increasing need for novel interconnect techniques and integration. Of interest is the development of new packaging methods for 3D integration. We seek developments that demonstrate vertical integration of sensors, front-end electronics, and data-processing elements utilizing novel interconnect techniques to enable low- mass tracking devices with excellent resolution in timing (~10 ps) and position (<= 5 microns). We also seek heterogenous integration techniques with non-silicon materials, such as large-bandgap materials, thin films, and other new emerging materials.

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

c. Electronics and Sensors for Ultra-Low-Temperature Experiments (4 K and Below)

Many HEP experiments are operated in the deep cryogenic regime (10–100 mK) with large numbers of readout channels required. Data acquisition and control signals from the mK stage out to room temperature require advanced sensors, high-fidelity RF signals, extremely low noise, and low thermal load on the cryogenic systems. Applications range from future CMB experiments that will have large focal plane arrays of superconducting detector elements, to axion dark matter searches with large channel counts to reach to high axion masses, to large-scale phonon-based particle-like dark matter searches.

Specific areas of interest include: superconducting passive and active components integrated into functional circuits and systems, such as superconducting logic gates, oscillators, filters, and analog-to-digital converters; low-noise cryogenic amplifiers (HEMT, SQUID, parametric, etc.); scalable high-density superconducting interconnects for microfabricated devices as well as small connectors with extremely low contact resistance (< 1 milliohm); high-density feed-through interconnects for mK to LHe to room temperature stages; and microfabrication techniques for superconducting sensor (e.g., TES, MKID, qubit), including micromachining, MEMS, and novel thin films.

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

References:

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C59-28. HIGH ENERGY PHYSICS DETECTORS AND INSTRUMENTATION

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

High Energy Physics experiments require specialized detectors for particle and radiation detection. As an example, high-priority future experiments in the DOE Office of High Energy Physics (HEP) portfolio need advances that can benefit from small business contributions. These experiments include potential upgrades to the High Luminosity Large Hadron Collider (HL-LHC) detectors currently under construction (see https://home.cern/science/accelerators/large-hadron-collider) or other potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., https://www.dunescience.org), next-generation direct searches for dark matter, and astrophysical surveys to understand dark energy, including cosmic microwave background experiments.

We seek small businesses to advance the state of the art and/or increase cost effectiveness of detectors needed for the above experiments and for the wider HEP community. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. Improvements in sensitivity, robustness, and cost effectiveness are sought. R&D towards these ends will typically be in progress at DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific detector areas, the scientists involved are the best source of detailed information about requirements and relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists to develop germane applications.
Clear and specific relevance to HEP programmatic needs is required and supporting letters from lab and university scientists are an excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov.

Grant applications are sought in the following subtopics:

a. Low-Cost, High-Performance (V)UV/Visible/Near-IR Photon Detection

Particle physics detectors need to cover large areas with high-sensitivity photodetectors. Requirements include various combinations of the following: 1) Wavelength sensitivity in the range 100–1500 nm over large photo-sensitive areas; 2) Fast response, radiation hardness, magnetic field compatibility, and high quantum efficiency for collider and intensity frontier experiments; 3) Compatibility with cryogenic operation and built with low- radioactivity materials for neutrino and dark matter experiments; and 4) Low cost and high reliability. Technologies using modern manufacturing processes and low-cost materials are of interest. These include use of semiconductor-based Geiger mode SPAD arrays, SiPM arrays and large-area microchannel plate-based systems (highly pixilated, fast readback with position resolution of less than ~0.3 mm and time resolution of ~10 ps for single photons).

For collider and intensity frontier experiments, grant applications are sought to develop wide-bandgap solid-state photodetector technologies with internal gain that have low dark current, good radiation hardness, and reduced gain sensitivity to temperature.

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

b. Scintillating Detector Materials and Wavelength Shifters

HEP utilizes scintillating materials for large calorimeters in colliding beam and intensity frontier experiments. Development of large (>100 cm^3), bright (>10,000 ph/MeV), fast (tens of ns), and radiation-hard (tens to hundreds of Megarad) ceramics or glasses with high density (>6 g/cm^3) are of interest for intensity frontier experiments, as well as for colliding beam experiments if high-volume (multi-m^3), cost-effective (few $\$/cm^3$) production methods can be developed. Scintillating crystals are not within the scope of this subtopic.

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

c. Vibration-Free Cooling Solutions for Low-Temperature Experiments

A vibration-free environment is essential for various low-temperature QIS and HEP experiments such as direct dark matter searches operating at temperatures below 0.1 K. Existing cooling solutions from vendors, like the "Helium-Battery" concept provide vibration-free operation but only for a limited amount of time. Proposals are sought for new concepts for a "dry" dilution refrigerator (utilizing, for example, pulse tube technology) that operates continuously in a vibration-free mode (<10^-7 g/sqrt(Hz), with g=9.81 m/s^2, in the 5-20 kHz range) at temperatures around 10 milli-Kelvin.

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

References:

1. U.S. Department of Energy, 2020DOE Basic Research Needs Study on High Energy Physics Detector Research and Development, BRN Report, https://science.osti.gov/hep/Community-Resources/Reports (June 29, 2023)
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C59-29. ARTIFICIAL INTELLIGENCE/MACHINE LEARNING FOR HIGH ENERGY PHYSICS

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

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Motivation:
HEP simulation, reconstruction, controls, and analyses have in recent years seen a transformation from Artificial Intelligence and Machine Learning (AI/ML) methods that allow to, respectively, (i) cut-short full, computationally-demanding simulations while remaining faithful to the correct physics, (ii) provide sophisticated detector objects derived from processing the particle energy-depositions in detectors, (iii) monitor beam-lines and instrumentation to provide feedback control, as well as trigger detectors, and finally, (iv) give intelligent inference of the physics under study in the event sample or images.

HEP has unique concerns and demands of the field of AI/ML: working with extremely large data sets streaming from multi-modal detectors and observatories is common to most experiments, as is the need for online monitoring and control of the facilities producing the data that are sensitive to environmental conditions and are constantly evolving through upgrades. AI/ML across generations of facility upgrades either to process and gain information from the data, or to provide real-time monitoring requires ever-larger sophistication and compute power.

Large data sets and continuous learning may be required to detect, monitor, and control HEP detection facilities. However, typically datasets over which training occurs, that might naturally be on the scale of petabytes, are frequently reduced to terabytes or gigabytes for convenience. In so doing, information may be lost or not properly captured as a function of time. Similarly, continuous learning can be employed to avoid model sensitivity to changing data input. Continuous learning avoids the need to train multiple models for each generation in a facility's evolution and for all possible conditions that may affect elements of the facility's performance.

Further to HEP needs, visualization of all aspects of the AI/ML process are desired. The HEP paradigm is to compare simulated data predictions with experimental data observations and visualization tools aid the process of drawing scientific conclusions. Tools that allow comparison between multiple datasets that may have data values spanning multiple orders of magnitude and represent physical systems are essential. Integrating HEP visualization with AI/ML software allows HEP scientists to gain insight into the ML network under study for a better physical interpretation of not just the extracted physics, but of the network and its performance. Further, the visualization of uncertainties in data sets is essential in drawing scientifically valid conclusions.

HEP seeks applications under this SBIR FOA that build software tools that are aligned with the above purposes. Applications are sought that conform to the following two descriptions. Letters of Intent should demonstrate the proposed tools will be relevant to specific AI/ML applications in more than one HEP sub-program, and the software developed will be usable in standard HEP AI/ML workflows to be considered responsive.

a. HEP AI/ML Training Tools

Software tools to facilitate training on PB scale datasets either through distributed, real-time, or asynchronous training; or algorithms for life-long learning of continuously evolving systems. Large scale data set training tools can be optimized for either homogeneous or heterogenous computing systems and may include training in multiple stages or with hyperparameter optimization. Continuous learning can be applied to algorithms that either adapt for data source evolution or a changing facility as a whole. These tools should be applicable for time-varying systems with an ability to adapt and utilize feedback, physics constraints, and active learning techniques.

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Questions – Contact: Jeremy Love, Jeremy.Love@science.doe.gov

b. HEP AI/ML Visualization Tools – Description

Software tools to improve visualization of scientific information natively integrated with both AI/ML and HEP software libraries. Applications submitted to this topic should focus on the ability to generate scientific publication quality plots of widely varying types of data and their associated uncertainties using a straightforward user interface; or develop visualization techniques to identify and display anomalous outcomes when comparing to reference data.

Questions – Contact: Jeremy Love, Jeremy.Love@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: Jeremy Love, Jeremy.Love@science.doe.gov

References:

1. U.S. Department of Energy, 2019, Basic Research Needs Workshop on Compact Accelerators for Security and Medicine, Tools for the 21st Century, May 6-8, 2019, https://science.osti.gov/-/media/hep/pdf/Reports/2020/CASM_WorkshopReport.pdf?la=en&hash=AEB0B318ED0436B1C5FF4EE0FDD6DEB84C2F15B2 (See sections 2.2 and 5.2.1-5.2.3) (June 29, 2023)
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PROGRAM AREA OVERVIEW: OFFICE OF NUCLEAR PHYSICS

Nuclear physics research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which in turn determines the essential physical characteristics of the universe. The primary mission of the Office of Nuclear Physics (NP) 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) in operation since 2000, forms states of matter which have not existed since the first moments after the birth of the Universe. It will cease operations soon to further the construction of the Electron-Ion Collider (EIC) on the same site. The EIC's goal is to further our understanding of the origin of the mass and spin of nucleons through the interactions of quarks and gluons. 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) produces and studies 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 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 molecules, where extremely low event rate particle detection in the presence of an extraneous background 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 Office of Nuclear Physics priorities, click here.

C59-30. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

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), for the Facility for Rare Isotope Beams (FRIB) at MSU, and from Europe, the Large Hadron Collider (LHC). The Electron-Ion Collider (EIC), being constructed at BNL is anticipated to produce data at rates challenging 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 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 up to a petabyte (PB) which are then distributed to institutions worldwide for analysis, and with the increasing data generation rates at these facilities, multi-PB reduced datasets are becoming common. Increased adoption of streaming readout protocols for the newest large instruments will only accelerate the volume of raw data. In tandem, 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 processed by means of custom software pipelines and archived for future analysis. These simulations are varied and can 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.
Innovative solutions addressing the management and storage of such large data sets beyond the current state-of-the-art will be required to support these large-scale nuclear physics activities.

Note that software applications for control or diagnosis of accelerator hardware or data should apply to Topic C59-32 Nuclear Physics Accelerator Technology.

All proposals must explicitly show relevance to the DOE Nuclear Physics (NP) program and must be informed by the state of the art in nuclear physics software and data management applications, commercially available products, and emerging technologies. A proposal 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 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.

Proposals 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

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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/.

Proposals are sought only in the following subtopics:

a. Tools for Large Scale Nuclear Physics Data Processing

A model amongst some nuclear physics communities 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. A different model exists for experiments creating the largest volumes of data, such as those for the Heavy Ion and Medium Energy communities, where data is stored and analyzed at centralized facilities and accessed by researchers across the world. Both models require tools for analyzing such large data sets.

Proposals are sought for:

1) Software techniques to improve the effectiveness of storing, retrieving, and moving large volumes of data (> 1 PB/day), possibly including but not limited to techniques such as 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. Such tools should be aligned with FAIR principles (findability, accessibility, interoperability, and reusability). Examples of such approaches might include fast information retrieval through advanced metadata searches or in-situ data reduction and repacking.

Open-source software solutions are strongly encouraged. Proposals 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 an application of use to a nuclear physics subprogram, e.g. Medium Energy, Heavy Ions, etc. and/or at a nuclear physics facility. All proposals must identify a current or future NP experiment or a data management facility interested in the deployment of the proposed tools. 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. Application of Emerging Data Science Techniques 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 experimental data, the data sets collected will be composed of a large number of events each 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 compute resource intensive task. Currently, both the national laboratory and university-based groups carrying out experimental and simulation analyses maintain local computing clusters using open source software packages, running domain specific software, often written by nuclear physicists using a dedicated instrument e.g., those at CEBAF, FRIB, and RHIC. Likewise, theoretical groups, after generating data on a multitude of HPC/LCF platforms, perform analysis either at those facilities or on local clusters. Concurrently, the nuclear physics, particle physics, and data science communities have 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. These tools are generally open-source and can be effectively deployed on platforms at the user's institution, a DOE National Laboratory, or on distributed computing resources provided by commercial cloud services. Application of these new ML and AI technologies to the analysis of nuclear physics data or to accelerate simulations requires the development of domain specific tools that do not require a steep learning curve. 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 C59-33 (Nuclear Instrumentation, Detection Systems and Techniques).

Proposals are sought to develop:

1) ML and AI technologies to address data analysis in a specific application domain in experimental, simulation, and/or theoretical nuclear physics. Proposals 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.
3) ML and AI technologies to realize a specific integrated accelerator - experiment dataset and its AI instrumentation for a cognizant facility from accelerator to detector to analysis.
4) ML and AI technologies that integrate methods in nuclear theory, simulations and data analysis to improve real-time decision making for nuclear physics experiments.

Applicants are strongly encouraged to consult the references and other relevant articles in the literature to best understand the AI/ML tools already in use by the community. Open-source software solutions are strongly encouraged. Proposals 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 an application of use to a nuclear physics subprogram, e.g. Medium Energy, Heavy Ions, etc. and/or at a nuclear physics facility. All proposals must identify a current or future NP experiment or theory collaboration interested in the proposed ML and AI technologies. 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

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. Utilizing DOE's High Performance Computing (HPC) and Leadership Computing Facilities (LCFs) is of growing relevance and importance to experimental NP as well. 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.

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Proposals 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 HPC/LCF architectures taking advantage of the parallel nature of analysis workflows and support the scheduling of GPU-intense and CPU-only workflows with sophisticated 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. Proposals 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 of use to a nuclear physics subprogram, e.g. Medium Energy, Heavy Ions, etc. and/or at a nuclear physics facility. All proposals must identify a current or future NP experiment or theory collaboration interested in the Heterogeneous Concurrent Computing technologies. 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 proposals 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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C59-31. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The DOE Office of Nuclear Physics (NP) seeks new developments in detector microelectronics with significantly improved energy, position, timing resolution, sensitivity, rate capability, stability, dynamic range, and background suppression. In general, the trend is moving towards very-large-scale systems-on-chip characterized by high functionality, high programmability, and digital signal processing (DSP) capabilities with high data rate interfaces. The application of these innovative readout microelectronics is for use with the nuclear physics detectors described in Topic C59-33 (Nuclear Instrumentation, Detection Systems and Techniques). An important criterion is the cost per channel of microelectronic devices and modules, and for some experiments, the power dissipated per channel should be below 1mW/channel.

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, from 77 K to below 20 mK. This underscores that, in general, nuclear physics microelectronics operate in extreme environments, whether at extreme cryogenic temperatures or where radiation levels are high. In some cases, magnetic fields in excess of 1.5 Tesla may also be present.

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All proposals must explicitly show relevance to the NP program. Proposals must be informed by the state of the art in nuclear physics applications, commercially available products and emerging technologies. A proposal 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 and Office of Science user facilities 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.

Proposals 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.

Proposals are sought only in the following subtopics:

a. Advanced Digital Processing Microelectronics

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

Proposals are sought to:

1) develop high speed digital processing electronics that can be either operated in triggered or streaming readout mode. The effective number of bits should be at least 14 at sampling rates of > 4GHz and a bandwidth > 2 GHz, with +/- 1LSB non-linearity, and +/- 1 LSB differential non-linearity. Such devices should have ≥ 16 channels with a credible design path to 64 channels with fast timing (< 10 ps). They should employ techniques for bandwidth reduction such as lossless compression, triggered based readout and zero suppression with options to bypass bandwidth reduction methods to allow full streaming modes if at a reduced sampling rate or channel count. Emphasis should be on low power dissipation and low cost per channel.

Proposals 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 Design and Fabrication: Manouchehr Farkhondeh, Manouchehr.Farkhondeh@science.doe.gov

b. Front-End Application-Specific Integrated Circuits

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Proposals 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. Superconducting microelectronics that advance the state-of-the-art are needed for some rare event detectors.

Microelectronics of specific interest include:

1) Highly-segmented detectors require high density, radiation-hardened amplifier/filters. ADCs/TDCs should have 16 bits of resolution (minimum 14 ENOB after accounting for integral and differential nonlinearities) for ADCs and 10ps resolution with 10us range for TDCs. The TDC should be multi-hit with common stop architecture. These microelectronics must survive fluxes of order 10 Mrad with 10^{15} n/cm^2. Native control and readout using fiber w/WDM so multiple ASICs can be serviced by one fiber is desired; and
2) High channel count ASICs for, as an example, superconducting nanowire single particle detector (SNSPD) arrays. These detectors require superconducting front-end ASICs for interfacing with these and other cryogenic (< 4 K) sensors. Requirements include ultra-low power (< 1mW/ch) large analog bandwidth (> 1 GHz) microelectronics and high channel count (64 channels desired). A TDC with these specifications is particularly sought.

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

Proposals 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 Design and Fabrication: Manouchehr Farkhondeh, Manouchehr.Farkhondeh@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites proposals 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 Design and Fabrication: Manouchehr Farkhondeh, Manouchehr.Farkhondeh@science.doe.gov

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C59-32. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

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 to advance accelerator technology and its applications to nuclear physics scientific research. In particular, advancing the relevant technologies of 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 to improve performance as well as availability are of particular interest. Also of interest are technologies relevant to the Electron-Ion Collider (EIC) being constructed at Brookhaven National Laboratory (BNL). These facilities make use of superconducting technologies, including superconducting radio frequency (SRF) accelerator components, superconducting magnets, with supporting infrastructure and technologies. Relevance to nuclear physics must be explicitly described, as discussed in more detail below.

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All proposals must explicitly show relevance to the DOE NP Program. Proposals must be informed by the state of the art in nuclear physics applications, commercially available products, and emerging technologies. A proposal 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.

Proposals 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/.

Proposals are sought only in the following subtopics:

a. Materials and Components for Accelerators at Nuclear Physics Facilities

Proposals are sought to improve or advance superconducting and normal-conducting materials or components for RF used in particle accelerators at NP facilities.

Areas of interest include;

1) peripheral components for both room temperature and superconducting structures, such as particulate-free bellows, NEG pumps, 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 *in-situ*, alternative techniques to dry ice and high-pressure water cleaning;
3) metal forming or other innovative fabrication techniques, with the potential for significant cost reductions by simplifying cavity sub-assemblies, by eliminating or reducing the number of electron beam welds. For elliptical cavities these may include improvements for dumbbells and end groups. For TEM-class cavities (e.g. low-beta), these may include drift-tubes, toroidal and domed geometries; and

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4) Methods to automate some aspects of cleanroom SRF cavity string assembly, such as robot assisted connections of cavities to one another, or resonators to the strongback, using vision system integration to improve efficiency of time, reduce human contamination, and reduce cost.

Proposals 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

Proposals are sought for innovative design approaches or techniques for the fabrication and operation of radio frequency accelerating structures and systems to potentially make an impact on the cost or improve the performance of accelerators at NP facilities.

1) innovative hardware-based 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) 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;

Proposals 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

c. Polarized Beam Sources and Polarimeters

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

1) Associated components for significantly improving and maintaining the performance of high current CW polarized electron sources for delivering beams of ~1-10 mA, or low rep rate polarized electron sources with bunch charges above 10 nC while maintaining longitudinal polarization greater than 90% and a photocathode quantum efficiency > 5% at ~780 nm;
2) absolute polarimeters for spin polarized 3He beams with energies up to 160 GeV/nucleon;
3) polarimeter capable of 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%; and,
5) 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. Proposals 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

d. Rare Isotope Beam Production Technology

Proposals are sought to develop:

1) 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;
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 ~104 Hz, 30 cm by 20 cm detection region; ~1mm position resolution for ions with Z>10;
4) Development of vacuum lubricant and bearings with radiation dose > 5 MGy (up to 50 MGy preferred) and thermal resistance up to 350 C. The outgassing rate of the lubricant should be less than 5e-5 torr L/s to maintain a vacuum level of 1e-6 torr. The bearing should support 5000 rpm operation; and
5) Development of high emissivity coating of targets or beam stops to enhance radiative heat transfer cooling in high radiation environments. The emissivity should be > 0.7 for infrared light (wavelength greater than 800 nm), and the area to be coated will be a disk of at least 40 cm in diameter. The emissivity should function at high temperatures (300 C) and in high vacuum of 1e-6 torr (outgassing rate < 5e-5 torr L/s). The coating should withstand an accumulated radiation dose of 500 MGy (up to 5 GGy is preferred).

Proposals 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

e. Accelerator Diagnostics

As accelerator facilities advance in their capabilities, it is important that diagnostics and controls keep pace. Proposals 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, proposals are sought for

1) non-intercepting 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

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3) non-intercepting devices/systems that measure the emittance of intense (>100 kW) CW ion beams

For heavy ion linear accelerator beam facilities, proposals 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/or 10 – 20 MeV/nucleon);
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; and
5) High-sensitivity non-intercepting BPMs for heavy 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;.

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

f. Other

In addition to the specific subtopics listed above, the Department invites proposals in other areas that fall within the scope of the topic description above. Before proceeding under this topic, please reach out to the contact below to discuss planned scope of work and its potential relevance to the DOE NP Program in Accelerator Technology.

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

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C59-33. NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The Office of Nuclear Physics (NP) supports R&D that leads 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, and upgrades to existing 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 Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory, and the proposed second detector for the Electron-Ion Collider (EIC) being constructed at Brookhaven National Lab (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 radioactivity and the ability to discriminate between a rare event of interest and more numerous residual background events is essential.

All proposals must explicitly show relevance to the DOE NP Program. Proposals must be informed by the state of the art in nuclear physics applications, commercially available products and emerging technologies. A proposal 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 and DOE Office of Science (SC) user facilities 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.

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Proposals 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.

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/.

Grant applications are sought in the following subtopics:

a. Advances in Detector 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. Proposals are sought to develop and advance the following types of detectors:

Particle identification and counting detectors such as:

1) Large area next generation Multigap Resistive Plate Chamber (MRPC) detectors with a low material budget capable of a very high-rate capability (≥200 kHz/cm^2) radiation hardness (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. Proposals for an accompanying readout system should be submitted to Topic C59-31, Nuclear Physics Electronics Design and Fabrication if interested in providing readout electronics.;

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 particle background) environments at an affordable cost that are designed to operate in a nonuniform (in strength and direction) magnetic field yet produce a uniform response across the detector. A design that is customizable for specific detection configurations is desired.

3) Next generation, heavy ion focal plane detectors or integrated detector systems for magnetic spectrometers and recoil separators with narrow time resolution (< 150ps FWHM), high energy loss resolution (<1%), high total energy resolution (<1%), and high position resolution (<0.4 mm FWHM) at high count rates (e.g. > 1Mcps);

4) Improved position resolution for Micropattern Gas Detectors (GEMs, Micromegas, MicroRWELLs, etc) and Parallel Plate Avalanche Chambers. Improvements include submillimeter position resolution (less than a few hundred micrometers) possibly by using novel readout plane geometries to lower 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). Refer to Topic C59-31, Nuclear Physics Electronics Design and Fabrication if interested in providing readout electronics.

Proposals 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. Technology for Rare Decay and Rare Particle Detection

Proposals 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 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.

Proposals 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).
3) Bolometers, including the required thermistors, based on cryogenic semiconductor materials, transition edge sensors, Superconducting Tunnel Junction (STJ) radiation detectors, or other new materials.;
4) Radiopure electronic components and cables for reading out sensors for neutrinoless double beta decay detectors and possibly quantum sensors. Of specific interest are capacitors, resonators, circuit substrates, connectors, and cables. The desired radioactivity of these components is typically < 100 parts-per-trillion 238U & 232Th (< 1 mBq/kg), though the exact requirements depend on the mass and location of the component with respect to the sensitive volumes of the experiment. In addition to radiopurity, the components must satisfy the specific electrical and thermal requirements (sensors typically operate at temperatures ranging from 165 K – 10 mK) specific to the particular neutrinoless double beta detector.
5) Novel methods capable of discriminating between interactions of gammas, charged particles, and neutrons in rare event experiments;
6) 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

Proposals 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. 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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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

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