

**U.S. Department of Energy
Small Business Innovation
Research (SBIR) and Small Business
Technology Transfer (STTR)
Fall 2026 Phase I Topics**



U.S. DEPARTMENT
of ENERGY

SBIR · STTR

Contents

Chapter 1: Applied Technologies Topics	3
Topic 1: Advanced Technologies for Domestic Critical Mineral Extraction, Midstream Processing, and Recycling	3
Topic 2: Innovations in Manufacturing and Scale-up for Energy Applications	5
Topic 3: State-of-the-Art Technologies for Industrial Competitiveness.....	8
Topic 4: Next-Generation Building Technologies.....	9
Topic 5: Cutting Edge Energy Generation and Power Management Technologies.....	9
Topic 6: Advanced Transportation Technologies and Fuels Production	11
Topic 7: Battery Technologies for Dual-Use Applications.....	13
Topic 8: Advanced Cybersecurity, Resilience, and Energy System Risk Mitigation Technologies	14
Topic 9: Innovative Technologies for Hydrocarbons and Geothermal Energy	14
Topic 10: Reactor Concepts Research, Development and Demonstration (Reactor Concepts RD&D) (RCRDD).....	15
Topic 11: Fuel Cycle Research and Development (FCR&D).....	16
Topic 12: Nuclear Energy Enabling Technologies (NEET)	17
Topic 13: Advanced Technologies for Used Nuclear Fuel and High-Level Waste Disposition	18
Topic 14: Grid Innovations to Strengthen, Enhance and Expand the Electric System’s Capacity, in a Cost Effective and Timely Manner.....	19
Chapter 2: Science Topics	20
Topic 15: Commercialization of ASCR/ECP-Funded Software.....	20
Topic 16: Cybersecurity for Scientific High-Performance Computing	23
Topic 17: Novel Instrumentation for X-ray and Neutron Facilities.....	24
Topic 18: Data, Synthesis, and Characterization Strategies for SI-Driven Materials and Molecular Systems Discovery	29
Topic 19: Enabling Technologies for Bioengineering and Quantum Science-Based Sensors.....	31
Topic 20: Fusion Fuel Cycle and Enabling Technologies	35
Topic 21: Advanced Particle and Radiation Detectors	36
Topic 22: High-Performance Electronics and Data Acquisition Systems	39
Topic 23: Multi-office SC topic - Innovative Accelerator Science and Technology.....	41
Chapter 3: National Nuclear Security Administration (NNSA) Topics	44
Topic 24: Proliferation Detection	44
Topic 25: Nuclear Detonation Detection	48

Chapter 1: Applied Technologies Topics

Emerging deep technologies and novel technical approaches not explicitly identified in the topics below may be considered under any Applied Office Topic, provided they directly address that topic's mission objectives, technical requirements, and intended outcomes. For example, quantum-enabled approaches or technologies and other advances in sensing, computing, materials, manufacturing, and related fields.

Topic 1: Advanced Technologies for Domestic Critical Mineral Extraction, Midstream Processing, and Recycling

This topic seeks small-business-led R&D projects that establish a direct technical and commercial connection between a feedstock provider and a processing technology developer to produce a defined intermediate material for specialty metal or specialty alloy production. Each proposal must focus on one mineral or secondary-resource system, one feedstock provider, a defined target element or set of co-products, and one overall processing objective. Responsive projects may address, for example, vanadium-bearing feedstocks; zircon- and hafnium-bearing heavy mineral sands; bauxite residue or red mud; slags, tailings, residues, or other underutilized mineral streams that can be processed into intermediates for use in specialty-grade materials for energy, defense, aerospace, nuclear, semiconductor, grid, industrial, or high-performance alloy supply chains. Vanadium, hafnium, and zirconium are included on the 2025 U.S. Critical Minerals List - which reflects supply-risk and national/economic security considerations - and are representative of the small global markets targeted by this topic.

Proposals addressing other target elements or minerals with comparable global market sizes are also responsive.

The motivation is to initiate practical processing activity for “small market” minerals that may be strategically important but are often overlooked because they are byproducts of primary production, technically complex, available only in limited volumes, or not yet connected to a qualified downstream customer. The desired Phase I outcome is not a full pilot plant or commercial facility. Rather, a successful project should create a credible bridge among a feedstock owner, a processor or separations technology developer, and, where feasible, a downstream producer or customer that converts the intermediate into, or uses it to produce, an application-qualified specialty metal or alloy.

Priority areas of interest are: (1) processing of a real, characterized feedstock into a specialty-metal-ready intermediate; (2) validation of the chemistry, mass balance, impurity profile, and preliminary product specification; and (3) establishment of a documented commitment between the raw material provider and the technology developer to continue scale-up if technical milestones are met.

Goals and Metrics

Applicants should clearly define the “pure” or upgraded form of material needed before it can enter specialty metal production. Depending on the mineral system, target products may include, but are not limited to, vanadium pentoxide, ammonium metavanadate, ammonium polyvanadate, or another vanadium precursor suitable for ferrovandium, vanadium alloy, or vanadium metal production; zirconium oxychloride, zirconium oxide, zirconium tetrachloride, hafnium-reduced zirconium intermediate, or another zirconium precursor suitable for specialty zirconium metal production; or hafnium oxide, hafnium oxychloride, hafnium tetrachloride, or another hafnium precursor suitable for hafnium metal, superalloy, plasma cutting, or nuclear applications. USGS identifies zircon as the principal economic source of

zirconium and the primary source of hafnium; it also notes that zircon commonly occurs as a co-product or byproduct of heavy-mineral-sands processing and that zirconium and hafnium occur together in zircon at roughly a 50:1 ratio. Comparable intermediate products from other mineral systems are also responsive where they meet the requirements of an identified specialty-metal, or specialty-alloy application.

Key R&D innovations sought include beneficiation, separation, extraction, impurity control, and intermediate-product finishing methods that can be demonstrated at bench scale using a real feedstock supplied by a resource provider. Technologies may include physical beneficiation, gravity separation, magnetic or electrostatic separation, flotation, roasting, acid or alkaline leaching, chlorination, carbochlorination, solvent extraction, ion exchange, selective precipitation, crystallization, calcination, hydrometallurgical flowsheets, pyrometallurgical upgrading, or hybrid processes. For a Phase I effort applicants should scope work around achievable outcomes: signed letter of support or feedstock access commitment; representative sample acquisition; independent feedstock characterization; bench-scale processing tests; production of gram- to kilogram-scale intermediate material, as appropriate; assay of the intermediate; preliminary impurity-removal strategy; mass balance; reagent and energy estimates; waste and water considerations; and a Phase II plan for larger sample processing, customer qualification, or pilot-scale validation.

Not of Interest

Projects are out of scope if they propose broad critical minerals exploration, geologic resource mapping, market studies, or literature reviews without processing real feedstock. Also out of scope are proposals that pursue multiple unrelated feedstocks, multiple unrelated elements, or “recover everything” approaches without a single defined target intermediate and measurable product specification. Projects using only synthetic feedstocks, simulated ores, reagent screening unconnected to a named resource provider, or generic separations chemistry without a clear mineral source would not meet the objectives of this topic.

This topic does not seek mining equipment development, final alloy development, end-use component testing, battery or electrolyte formulation, bulk commodity production, or construction of a full processing facility. Cementitious reuse of red mud, construction-material applications, or waste stabilization without specialty metal recovery are not responsive. Routine contract analytical services, general consulting, equipment purchases without technical innovation, or projects that cannot identify a specific feedstock provider and credible downstream use case are also out of scope.

References

1. *Final 2025 List of Critical Minerals*, 90 Fed. Reg. 50,494 (Nov. 7, 2025), <https://www.federalregister.gov/documents/2025/11/07/2025-19813/final-2025-list-of-critical-minerals>.
2. U.S. Geological Survey, *Zirconium and Hafnium Statistics and Information*, <https://www.usgs.gov/centers/national-minerals-information-center/zirconium-and-hafnium-statistics-and-information> (last visited Aug. 7, 2026).
3. James V. Jones III, Nadine M. Piatak & George M. Bedinger, *Zirconium and Hafnium*, U.S. Geological Survey Professional Paper 1802–V (2017), <https://doi.org/10.3133/pp1802V>.
4. U.S. Geological Survey, *Vanadium Statistics and Information*, <https://www.usgs.gov/centers/national-minerals-information-center/vanadium-statistics-and-information> (last visited Aug. 7, 2026).

5. U.S. Dep't of Energy, *2023 DOE Critical Materials Assessment* (2023), https://www.energy.gov/sites/default/files/2023-07/doe-critical-material-assessment_07312023.pdf.
6. U.S. Dep't of Energy, *What Are Critical Minerals and Materials?*, <https://www.energy.gov/cmm/what-are-critical-minerals-and-materials> (last visited Aug. 7, 2026).
7. U.S. Geological Survey, *Critical Mineral Resources in Heavy Mineral Sands of the U.S. Atlantic Coastal Plain* (June 26, 2019), <https://www.usgs.gov/centers/gggsc/science/critical-mineral-resources-heavy-mineral-sands-us-atlantic-coastal-plain>.
8. Bradley S. Van Gosen et al., *Deposit Model for Heavy-Mineral Sands in Coastal Environments*, U.S. Geological Survey Scientific Investigations Report 2010–5070–L (2014), <https://doi.org/10.3133/sir20105070L>.
9. Bridget R. Scanlon et al., *Gulf Coast Basin CORE-CM Initiative Final Report*, Technical Report DOE-Univ-TX-BEG-000236-14 (Univ. of Tex. at Austin, Bureau of Econ. Geology 2025), <https://doi.org/10.2172/3009720>.
10. U.S. Env't Prot. Agency, *TENORM: Bauxite and Alumina Production Wastes* (May 4, 2026), <https://www.epa.gov/radiation/tenorm-bauxite-and-alumina-production-wastes>.

Topic 2: Innovations in Manufacturing and Scale-up for Energy Applications

This topic focuses on advancing innovations that expedite the scaling up of manufacturing for materials, components, devices, equipment, and production processes essential for energy applications. Projects under this topic are intended to enhance any manufacturing pathway relevant to energy where technical innovation can lead to improvements in manufacturability, production readiness, domestic supply capability, quality, cost, throughput, reliability, or energy productivity.

Application areas covered include batteries and energy storage, power electronics and semiconductors, advanced conductors, magnets, grid hardware, components for power generation systems (such as gas, nuclear, hydropower, and geothermal), recycling and remanufacturing, as well as other energy-related materials, parts, or systems.

A particular area of interest is the advancement of high throughput “micro-scale” manufacturing. At present, photolithography on thin films for semiconductor chip manufacturing is the only widely established micro-scale technology. This technique has provided significant benefits to both the U.S. and global economies. However, recent draft R&D roadmaps from CMEI highlight the need to scale up additional micro-scale manufacturing techniques. Such advancements would support industries including microelectronics, power electronics, battery manufacturing, and associated equipment.

These emerging techniques include field-assisted technologies that utilize magnetic, mechanical (such as strain fields), acoustic, electromagnetic, or light-assisted fields. The motivation behind this research area stems from the observation that many energy technologies face challenges transitioning from laboratory validation to commercial production. The primary barriers are manufacturing processes that lack sufficient repeatability, economic viability, energy efficiency, cybersecurity, qualification, or compatibility with existing production infrastructure.

Areas of Interest

Specifically, this topic seeks applications in the following priority areas of interest:

a. Scale-up of advanced manufacturing processes for energy materials, components, and devices

Illustrative technologies: advanced forming, joining, welding, coating, casting, additive manufacturing, powder processing, machining, roll-to-roll processing, electrochemical processing, separations, critical-materials refining, recycling, remanufacturing, thermal processing, semiconductor and power-electronics manufacturing, battery electrode and cell manufacturing, and manufacturing approaches for large, complex, high-performance, or safety-critical energy components.

Goals and metrics: Applicants must state a specific, measurable target metric related to the scale-up bottleneck they are addressing, such as throughput (units or mass per hour); first-pass yield; defect or scrap rate; cost per accepted unit; energy use per accepted unit; material utilization; or qualification/certification timeline.

b. Modular, flexible, and retrofit-ready manufacturing platforms that reduce the time and cost of moving from prototype to pilot or early production

Illustrative technologies: modular or reconfigurable tooling, retrofit kits or interfaces for legacy production equipment, flexible platforms supporting multiple product variants or rapid changeover, and standardized modular units for pilot-to-production scale-up.

Goals and metrics: Applicants must state a specific, measurable target metric related to reduction of the time and cost of moving from prototype to pilot or early production, such as reduction in prototype-to-pilot transition time; reduction in retrofit or changeover cost; reduction in capital cost per unit of production capacity; or increase in the number of product variants or process conditions supported without major re-tooling.

c. Smart manufacturing tools that enable real-time process understanding, quality control, digital qualification evidence, and secure supply-chain visibility

Illustrative technologies: in-line metrology, nondestructive evaluation, multimodal sensing, robotics and automation tied to a manufacturing process, machine vision, edge analytics, digital twins, physics-informed models, SI-enabled design of experiments, closed-loop process control, secure data infrastructure, digital-thread architectures, and traceability or provenance systems.

Goals and metrics: Applicants must state a specific, measurable target metric related to real-time process understanding, quality control, digital qualification evidence, and secure supply-chain visibility, such as reduction in defect escape rate; reduction in inspection or qualification time; improvement in process capability; reduction in unplanned downtime; or a measurable increase in the share of process data captured in a machine-readable, standards-compliant, and traceable format. Where digital or SI-enabled systems are proposed, applicants must also address model validation, data quality, uncertainty, cybersecurity, operator usability, and integration with existing equipment or legacy manufacturing environments.

Goals and Metrics for Topic 2 Areas of Interest

Key R&D innovations sought include methods that improve transition from bench-scale or prototype demonstrations to pilot-scale or production-relevant operation. Proposals should define the target material, component, device, or process; the current scale or maturity level; the limiting manufacturing barrier; and measurable outcomes.

To qualify as responsive, an innovation must target a specific manufacturing bottleneck related to energy materials, components, devices, equipment systems, or production processes. The main technical risk should involve issues with manufacturability, scaling up production, process management, qualification, or production costs. Phase II projects are required to showcase and integrate a prototype within a relevant manufacturing setting, operating at sufficient scale,

duration, and duty cycle to assess repeatability, reliability, interoperability, safety, cybersecurity, and cost efficiency.

Projects will not be considered if they work solely on basic material discovery, lab-scale synthesis, computational filtering, product performance, or energy-system modeling without a clear focus on manufacturing or scaling up. Also excluded are proposals that mainly buy commercial equipment, conduct routine process improvements, do market research, offer consulting services, or develop training materials without unique technical R&D contributions. Custom demonstrations without a reliable path toward broader use, repeated deployment, or commercialization are also nonresponsive.

Generic software tools do not qualify unless they specifically resolve challenges like manufacturing scale-up, process control, quality assurance, qualification, or production costs for an energy application. Nonresponsive examples include general dashboards, enterprise resource planning tools, scheduling platforms, independent predictive maintenance software, or generic SI models not validated in manufacturing contexts. Projects that only handle post-process inspection without boosting manufacturability, feedback, quality control, or readiness for scaling up will not meet topic goals. Technologies demanding classified operations, unsafe autonomous controls for critical systems, unsupported claims of market readiness, or digital solutions like blockchain or large language models used independently rather than integrated into a manufacturing solution are all out of scope.

References

1. Energy Act of 2020, section 6006. Energy Act of 2020, Pub. L. No. 116-260, div. Z, tit. VI, § 6006, 134 Stat. 2418, 2560 (2020) (codified at 42 U.S.C. § 17115a). See Energy Act of 2020, U.S. Congress (2020), <https://www.congress.gov/116/plaws/publ260/PLAW-116publ260.pdf>.
2. U.S. Dep't of Energy, National Smart Manufacturing Strategic Plan: To Facilitate More Rapid Development, Deployment and Adoption of Smart Manufacturing Technologies (July 2022), <https://doi.org/10.2172/1880185>.
3. National Academies, Options for a National Plan for Smart Manufacturing. Nat'l Acad. of Scis., Eng'g & Med., *Options for a National Plan for Smart Manufacturing* (Nat'l Acad. Press 2024), <https://doi.org/10.17226/27260>.
4. National Strategy for Advanced Manufacturing, Subcomm. on Advanced Mfg., Comm. on Tech., Nat'l Sci. & Tech. Council, *National Strategy for Advanced Manufacturing* (Oct. 2022), <https://www.energy.gov/sites/default/files/2024-03/National-Strategy-for-Advanced-Manufacturing-10072022.pdf>.
5. Alaa Elwany, Christopher Hovanec & Nick Lalena, Near Net Shape Workshop Report (U.S. Dep't of Energy Feb. 2024), <https://doi.org/10.2172/2316044>.
6. U.S. Dep't of Energy, Genesis Mission: A National Mission to Accelerate Science Through Artificial Intelligence, <https://genesis.energy.gov/> (last visited Aug. 7, 2026).
7. OMB Memorandum M-25-21. Off. of Mgmt. & Budget, Exec. Off. of the President, Memorandum M-25-21, *Accelerating Federal Use of AI Through Innovation, Governance, and Public Trust* (Apr. 3, 2025), <https://www.whitehouse.gov/wp-content/uploads/2025/02/M-25-21-Accelerating-Federal-Use-of-AI-through-Innovation-Governance-and-Public-Trust.pdf>.
8. Exec. Off. of the President, *Winning the Race: America's AI Action Plan* (July 2025). See *Winning the Race: America's AI Action Plan*, Exec. Off. of the President (2025), <https://www.whitehouse.gov/wp-content/uploads/2025/07/Americas-AI-Action-Plan.pdf>.
9. Nat'l Inst. of Standards & Tech., U.S. Dep't of Com., *Guide to Operational Technology (OT) Security*, NIST Special Publication 800-82 Rev. 3 (Sept. 2023),

<https://doi.org/10.6028/NIST.SP.800-82r3>, 2023). See Guide to Operational Technology (OT) Security, NIST Special Publication 800-82 Rev. 3, Nat'l Inst. of Standards & Tech. (2023), <https://doi.org/10.6028/NIST.SP.800-82r3>.

10. Int'l Soc'y of Automation, ISA/IEC 62443 Series of Standards, <https://www.isa.org/standards-and-publications/isa-standards/isa-iec-62443-series-of-standards> (last visited Aug. 7, 2026).
11. NIST SP 800-161. Nat'l Inst. of Standards & Tech., U.S. Dep't of Com., *Cybersecurity Supply Chain Risk Management Practices for Systems and Organizations*, NIST Special Publication 800-161 Rev. 1, Update 1 (May 2022, updated Nov. 1, 2024), <https://doi.org/10.6028/NIST.SP.800-161r1-upd1>

Topic 3: State-of-the-Art Technologies for Industrial Competitiveness

The U.S. Department of Energy's (DOE) Industrial Technologies Office (ITO) is supporting an Open Topic for state-of-the-art technologies that strengthen America's industrial sector and advance global competitiveness of U.S. industry through step-change improvements in energy productivity, process efficiency, and performance, cost, and other relevant areas.

Areas of Interest

Applications to this topic should address one of ITO's research, development, and early-stage demonstration (RD&D) focus areas:

a. Sector-specific process innovation for the largest industrial consumers of energy:

Chemicals & Refining, Iron, Steel, & other Commodity Base Metals, Food & Beverage, Forest Products, and Cement, Concrete, & other Building Materials.

b. Innovation on common unit operations applicable across many industrial sectors:

Thermal processes (combustion, combined heat and power systems, heat exchangers, waste heat recovery, electrotechnologies, and thermal energy storage), non-thermal processes (membranes, comminution, and other separations), and the Water-Energy Nexus (water supply, wastewater treatment, and PFAS destruction).

c. Innovation that enables the integration of data centers and other large loads into the energy systems: such as data center thermal management, power systems, and demand-side load flexibility.

Not of Interest

- Technologies that do not address a specific industrial need or are not directly relevant to one or more industrial focus areas.
- Technologies that are primarily relevant for non-industrial sector applications (e.g., power sector).
- Further development of technologies that are mature or commercially available.
- New system designs, configurations, and/or integration that primarily incorporate commercially available or mature technologies.
- Innovations in carbon capture and storage.
- Innovations in hydrogen production and transportation.

Note: To increase the likeliness of industry adoption, applications for this topic must demonstrate clear evidence of commercial potential that combines technology progress (e.g. demonstrated analytical and experimental proof of concept in a laboratory environment) with

significant market pull (e.g. demonstrated interest from industry partners, investors and/or off takers).

Applications should identify the path towards commercialization beyond SBIR funding – potential sources, stages, timing, amounts, and types of subsequent financing required to reach market.

Topic 4: Next-Generation Building Technologies

BTO seeks innovative proposals that can lower both the up-front cost of new energy-saving technologies and operational energy use for consumers. Topics of interest include air and water heating, ventilation, air conditioning, and refrigeration systems; technologies that optimize building operations, including technologies that enable energy system integration; and technologies for improving building envelopes in new and existing buildings and saving costs across all sectors and regions.

Areas of Interest

While any topics that address the topic are welcome, specific areas of interest include:

a. Technologies that simplify dual-fuel heating, ventilation, and air conditioning (HVAC): including on-board, building-level, and utility-level controls. The technologies should streamline system optimization, improve fuel switchover logic, enhance energy system flexibility, and reduce commissioning and maintenance burden. Complete low-cost, dual-fuel HVAC systems could be responsive to this area.

b. Control and modeling technologies that use super intelligence (SI) or machine learning to save time and money for customers: The technologies should allow consumers to export data and leverage third-party platforms, making their data easier to use.

Not of Interest

Proposals out of scope: Software that simply aggregates third party data or displays it (e.g. an analytic or dashboard application) is out of scope, as are SI-enabled information systems that do not have integrated controls or data collection.

Topic 5: Cutting Edge Energy Generation and Power Management Technologies

The U.S. Department of Energy's (DOE) Hydropower and Hydrokinetic Office (H2O) and Integrated Energy Systems Office (IESO) are supporting an Open Topic for Cutting Edge Energy Generation and Power Management Technologies that will bring new sources of reliable, affordable, and secure energy to the grid.

The Integrated Energy Systems Office [1] drives research and development of energy solutions that enhance grid reliability and resilience, foster U.S. technological leadership, and reduce the cost of energy for Americans. The Hydropower and Hydrokinetic Office [2] enables research, development, testing, and commercialization of technologies to advance next-generation hydropower, pumped storage systems, and marine energy to deliver flexible, reliable energy, as well as advances integrated energy-water technology solutions [3,4]

Areas of Interest

Applications to this topic should address innovative technologies within the missions of the Offices.

Hydropower and Hydrokinetic Office

a. Hydropower and Pumped Storage

b. Marine Energy

- Co-development of marine energy technologies with end users
- Innovations in marine energy subsystems and components

c. Integrated Energy-Water Technology Solutions

Integrated Energy Systems Office

d. Aero Mechanical Energy Systems

- Innovations for economical recycling of wind energy technologies that would reduce waste, recover critical minerals, and/or reduce the cost of wind component recycling [5].
- Innovations for maximizing performance and/or reliability of existing wind energy assets [6].

e. Thermal Energy Systems

- Innovations to reduce costs and improve the reliability of solar-thermal components and integrated systems for deploying Solar Heat for Industrial Processes (SHIP) with thermal energy storage. Key applications include produced water thermal-desalination, remote mining, fuel conversion, growth of the food and beverage industry, manufacturing and other high temperature industries.
- Innovations that streamline operations, enhance reliability, and boost performance across solar-thermal fields and plants [7].

f. Advanced Photovoltaics

- Innovations for low-cost, reliable space photovoltaic (PV) panels that are less reliant on critical materials and have the potential to be fabricated with high-volume-manufacturing-compatible methods. Innovations include but are not limited to advancements in III-V wafer reuse, high-performance durable silicon PV for space deployment, perovskite manufacturing and stability, and perovskite manufacturing equipment and metrology development.
- Technologies and innovations for economical recycling of PV technologies that will increase the volume and value of recovered minerals and materials, particularly silver, silicon, copper, tellurium, glass, aluminum, and steel.
- Innovations for maximizing performance and/or reliability of existing PV cells, modules, and fleets.

g. Systems Integration, Interconnection, and Analysis

- Innovations to address potential cybersecurity threats to integrated energy systems arising from distributed energy resources and their supply chains.
- Innovations in power electronic system control technologies to improve grid stability and reduce system outages.

h. Permitting and Impact Reduction

- Innovations that increase the safety of plug-in PV systems, including those that address the technical issues of breaker masking and back-feed.

- Innovations that can track and monitor permitting processes, and/or increase capacity for state and local governments and/or developers to improve permitting timelines and outcomes.

Not of Interest

Technologies that are specifically not of interest for this topic include:

- Carbon capture
- Hydrogen production
- Offshore wind technologies, including hybrid wind/marine energy generation systems
- Non-concentrating solar-thermal systems
- Geothermal energy technologies, fossil energy technologies, or nuclear energy technologies
- Battery chemistry

References

1. Integrated Energy Systems Office, U.S. Department of Energy, <https://www.energy.gov/cmei/systems/integrated-energy-systems-office>.
2. Hydropower and Hydrokinetic Office, U.S. Department of Energy, <https://www.energy.gov/cmei/water/hydropower-and-hydrokinetic-office>.
3. Multi-Year Program Plan, U.S. Department of Energy, <https://www.energy.gov/cmei/water/multi-year-program-plan>.
4. Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), U.S. Department of Energy, <https://www.energy.gov/cmei/water/small-business-innovation-research-sbir-and-small-business-technology-transfer-sttr>.
5. Wind Turbine Recycling Assessment Report: Guide for the Recycling Industry, U.S. Department of Energy, <https://www.energy.gov/cmei/systems/wind-turbine-recycling-assessment-report-guide-recycling-industry>.
6. Blade and Drivetrain Testing Advance Wind Turbine Efficiency and Reliability, U.S. Department of Energy, <https://www.energy.gov/cmei/systems/articles/blade-and-drivetrain-testing-advance-wind-turbine-efficiency-and-reliability>.
7. National Laboratory of the Rockies (NLR), First Solar Thermal Energy Planner (STEP 1) and Nationwide Industrial Heat and Power Analysis, NLR/TP-5700-96614, 2026, <https://www.energy.gov/cmei/systems/integrated-energy-systems-office>.

Topic 6: Advanced Transportation Technologies and Fuels Production

Alternative Fuels and Feedstocks Office, AFFO (<https://www.energy.gov/cmei/fuels/alternative-fuels-and-feedstocks-office>) comprising portfolios in bioenergy and hydrogen and fuel cells, enables RD&D to accelerate technology commercialization for the production, storage, delivery and use of alternative fuels, chemicals, and feedstocks. Transportation Technologies Office (TTO) funds RD&D and deployment of innovative, efficient, and affordable transportation solutions.

This topic seeks innovative transportation and fuel solutions and complementary technologies to enhance the security and reliability of energy networks, lower energy costs for Americans, and provide consumers with more options.

Areas of Interest

a. Production of Chemicals and Fuels from Alternative Feedstocks: Novel production, or process intensification, of cost-competitive organic chemicals, fertilizers, and strategic liquid

fuels from hydrogen, biomass, and waste (e.g., municipal or industrial waste or resource recovery from nuclear power plants, data centers, mine tailings, wastewater, end-of-life tires, etc.)

b. Fuel Cell System Technologies: Fuel cell systems (e.g. SOFC, PEMFC) that efficiently convert gaseous fuels (e.g. hydrogen, natural gas or biogas) into electricity to provide affordable, MW-scale prime and/or backup power for U.S. data centers and other growing electrical loads. Innovative concepts to improve performance and durability, and lower costs of fuel cell materials, components, and balance of plant. Technology advancement should demonstrate potential to meet 2030 stationary fuel cell targets including 80,000 hours durability and a capital cost of \$1000/kW for systems operating on natural gas and \$600/kW with direct hydrogen.

c. Fuels and Feedstocks Delivery and Storage: Hydrogen delivery and storage technologies that support large-scale hydrogen transfers. Novel concepts to reduce capital or operating cost, increase durability, and improve performance of components and systems. Concepts should compare the proposed approach to current state-of-the-art technologies.

d. Automotive Materials: SI-driven smart polymer matrix composite material systems to enable early detection of battery thermal runaway and electromagnetic interference (EMI) shielding through optimization of material interfaces, load transfer, and multifunctionality, embedded sensing and SI-driven diagnostics that will enhance public safety. The smart composites are anticipated to provide the following functionalities, aiming for an electromagnetic interference (EMI) shielding effectiveness >30 dB, a battery thermal runaway detection threshold ≤ 130 °C, and a fiber-to-resin load transfer efficiency >87%.

e. Advanced Motors and Power Systems: Advancements in cost-effective traction motors and power electronics for vehicle traction drives that reduce reliance on foreign supply chains, including rare earth elements and other relevant critical minerals. There is especially an interest in heavy rare earth (HRE)-free magnets for use in electric motors designs that can meet vehicle minimum requirements. Solutions must meet these minimum electric drive requirements for a full hybrid vehicle (HEV): bus voltage: 200-400 V; peak power: 40-100 kW; power density: ≥ 50 kW/L.

f. Off-Road, Rail, Marine and Aviation: Develop and demonstrate a powertrain optimization software tool which improves efficiency and reduces criteria emissions for hybrid electric off-road or mining vehicles. The tool may provide energy efficiency calculations for hybrid powertrains, route/cycle optimizations (with or without automation), and/or inter-vehicle connectivity. The final product should be available for integration in representative off-road or mining vehicles.

g. Energy Efficient Mobility Systems: Improvements in vehicle automation, traffic management, intermodality, or other technologies that improve system wide energy performance and affordability of passenger or freight transportation. Examples include, but are not limited to, cooperative adaptive cruise control/vehicle platooning, traffic signal optimization and/or traffic signal vehicle V2I applications, and mixed mode delivery fleet assignment and dispatch management software. Non-responsive examples included, but are not limited to, software applications that merely connect customers to transportation providers and tracking systems that merely provide emissions and fuel-use data to customers.

Not of Interest

Specific technologies NOT of interest:

- Fuel cells and batteries for on-road transportation applications
- Reversible fuel cells for energy storage applications
- Liquid-fueled fuel cells

Topic 7: Battery Technologies for Dual-Use Applications

Rechargeable batteries (primarily Li-ion) have demonstrated utility in an expanding number of commercial and defense applications in recent years. Battery technology, manufacturing, and critical mineral supply chains are closely aligned regardless of use case; therefore, further innovation to improve battery performance and cost and secure U.S. battery supply chains in the consumer sector is key to supporting cutting-edge defense capabilities.

This topic seeks cell-level demonstration of innovative secondary batteries with near-term prospects for commercial use (e.g., consumer electronics, transportation, battery backup unit/grid storage) and justification of defense-related use (e.g., UAS, UUV, soldier-carried systems).

Goals and Metrics

All must be included to be considered responsive.

- Focus: improved materials, components, electrodes, cell design implemented in full cell.
- Commercialization plan addresses risks and challenges manufacturing, scale-up, and supply chain considerations and how these can be mitigated or overcome, including NDAA compliance, for the chosen commercial and military market/application. Letters of support are highly desirable.
- Discusses suitability/ease of adaptation of technology to dual use, including cell form factor, safety, and performance (energy density, rate, temperature range, cycle life).
- Electrochemical test data must include details of temperature, applied pressure, cycling rate, AAM/CAM, electrode loading, V range, and cell size and format.
- Planned deliverables: at least 5 cells for each Phase I ≥ 200 mAh; Phase II ≥ 2 Ah cells for third-party testing at Idaho National Laboratory.
- Deliverables will meet Column A in table; justify meeting Column B in scaled-up form (i.e., large-format pouch, including fixturing, or prismatic) with model.
- Proposed battery technologies should meet or exceed all these minimum standards:

Minimum Performance Value		
Characteristic (Cell-level)	Column A - Cell Deliverable at End of Phase II	Column B -Capability in Scaled-Up Cell
Specific energy* (Wh/kg)	250	400
Energy density (Wh/L)	500	800
Peak power density (W/kg)	500	800
Cycle life**	250	1,000

*Specific energy measured at C/2; **Cycle life for 1C discharge, C/2 charge, 80% initial capacity and power

Not of Interest

Non-responsive: technologies incapable of meeting all thresholds set above and those far from commercial realization.

Topic 8: Advanced Cybersecurity, Resilience, and Energy System Risk Mitigation Technologies

The Office of Cybersecurity, Energy Security, and Emergency Response (CESER) seeks innovative technologies, tools, and methods that strengthen the cybersecurity, resilience, and operational continuity of the Nation's energy infrastructure and associated systems. CESER's mission priorities emphasize advancing cyber-risk discovery, mitigation, and response; accelerating technology transition for energy-sector security; enhancing situational awareness; and supporting the operational readiness of utilities and critical energy facilities. In alignment with recent CESER R&D portfolios, including efforts in advanced cybersecurity applications, industrial control systems (ICS) testing, cyber-informed engineering, supply-chain security, risk analytics, and resilience preparedness – this topic invites solutions that can mature into commercially viable capabilities for industry adoption.

Technological innovation is essential as energy systems become more distributed, digitally integrated, and exposed to evolving cyber and physical threats. Applicants are encouraged to propose novel architectures, SI-enabled analytic methods, advanced hardware or firmware security approaches, resilient operational technologies, and next-generation mitigation or response tools that address high-impact risks across electric, oil, natural gas, and emerging energy systems. Solutions that support operational resilience, including improved threat detection, attack containment, autonomous response, system recovery, or hardened design principles, are of interest.

Proposals may address any stage of the cyber-resilience ecosystem: vulnerability identification, threat-informed engineering, grid-architecture-based risk assessments, secure-by-design component development, supply-chain assurance concepts, or technologies that facilitate rapid restoration after compromise or disruption.

Topics should emphasize strong potential for commercialization, interoperability with energy-sector environments, and applicability to energy sector operations and mission-critical infrastructure. While technical creativity is encouraged, solutions must remain grounded in CESER's mission space, which includes cybersecurity for operational technology, industrial control systems, digital component supply chains, advanced analytics, and resilience measures for grid operations.

A broad range of technical approaches may be responsive to this topic provided they advance cybersecurity and resilience outcomes in the energy sector, promote cost-effective operational deployment, and demonstrate a pathway to measurable impact on sector security and continuity.

Topic 9: Innovative Technologies for Hydrocarbons and Geothermal Energy

The Hydrocarbons and Geothermal Energy Office (HGEO) mission is to unleash the full potential of America's hydrocarbon and geothermal resources to provide affordable, reliable, and secure energy. HGEO will only fund proposals that support the goals of the HGEO strategic plan (<https://www.energy.gov/hgeo/hgeo-strategic-plan-advancing-american-energy-dominance-security-and-global-leadership-0>) and drive technologies toward commercialization.

Areas of Interest

DOE/HGEO is seeking proposals that bring new cutting-edge technology to the marketplace to be applied in the recovery and use of coal, oil and gas, and geothermal resources. We are especially seeking technologies that improve the efficiency of any of these energy value chains, especially those which will extend the life of existing resources, such as real-time sensors for produced water, advanced materials, optimization methodologies and software, conformance technologies for hydrocarbon and geothermal energy extraction, or technoeconomic and/or market analysis supporting commercialization.

In the coal sector, we seek to invest in technologies that modernize existing coal mines and coal-based power plants, as well as support the growth of coal-based power and valuable co-products. These could involve improving the efficiency of extraction, capture, processing, and power generation at any stage in the value chain. (<https://www.energy.gov/hgeo/fy-2026-27-sbirsttr-additional-information>) In the oil and gas sector, we seek technologies to cost-effectively improve the recovery factor in unconventional reservoirs, create value from produced water, improve the efficiency and reliability of midstream infrastructure, and provide low cost baseload power and valuable co-products. Technologies to advance the beneficial use of produced water beyond the oil field and the development of near real-time sensors are of special interest. (<https://www.energy.gov/hgeo/fy-2026-27-sbirsttr-additional-information>) In the geothermal sector, we seek technologies and methods to improve targeting of the most promising resources and accelerate the development of new sources of geothermal energy as well as optimization of existing systems. We also seek methods and technologies that will support the use of geothermal for storage that enhances the reliability of the electric grid. (<https://www.energy.gov/hgeo/fy-2026-27-sbirsttr-additional-information>) HGEO is especially seeking technologies that will make a substantial impact on the market and significantly improve the ultimate economic recovery of subsurface energy resources.

Not of Interest

HGEO is NOT seeking technologies that focus solely on the separation and processing of critical minerals found in coal without a primary focus on the processing of the coal and carbon itself. HGEO is not seeking technologies whose sole purpose is to capture or store carbon from hydrocarbon-based power without associated enhanced energy recovery or beneficial product development. HGEO is not seeking proposals focused on developing or bench-scale testing of novel treatment or desalination technologies or that address standard deep-well disposal (Class II injection) or the routine recycling solely for hydraulic fracturing makeup water. HGEO is not seeking proposals focused on residential-scale or small-scale geothermal direct use systems or offshore geothermal exploration or characterization.

Topic 10: Reactor Concepts Research, Development and Demonstration (Reactor Concepts RD&D) (RCRDD)

The primary mission for the Office of Nuclear Energy (NE) is to advance nuclear energy science and technology to meet key energy resilience and economic needs in the United States. Proposed projects must demonstrate a strong tie to at least one of NE's three major goals: keeping existing U.S. nuclear reactors operating, deploying new nuclear reactors, and securing and sustaining nuclear fuel cycles.

To address the challenges facing the existing fleet and the development and deployment of nuclear energy systems, this topic area targets possible solutions needed for reactor sustainability and advanced reactor development and deployment, including high temperature gas-cooled reactors (HTGRs), sodium-cooled fast reactors (SFRs), molten salt reactors (MSRs), microreactors, light water small modular reactors, space power reactors, and other

concepts. Applications are sought with special emphasis on bridging gaps between early-stage research and commercialization. By funding projects in the areas of interest below, NE aims to build a resilient, secure, highly automated, and economically competitive nuclear infrastructure for both the existing fleet and advanced reactors.

Areas of Interest

Areas of particular interest include, but are not limited to:

- Graphite component development and lifecycle support to enable deployment of high temperature gas reactors (HTGR) and Molten Salt Reactors (MSR).
- Thermal hydraulic development to support HTGRs.
- Liquid metal reactor components including electromagnetic pumps, roller bearings (radial and thrust) for refueling sodium reactors, oxygen sensors.
- Supercritical CO₂ (sCO₂) components including heat pipe heat exchangers, high speed and high-power electronics for controlling permanent magnet rotors, and high temperature seals for high-speed rotating components.
- MSR technology development, including MSR components and systems (e.g., valves, pumps, gaskets, and heat exchangers); supply chain development for salt synthesis, purification, isotope enrichment, recycling, transport, and storage; and radionuclide management.
- Integration of nuclear power plant heat for industrial production purposes, including development of components that enable high-temperature nuclear applications.
- Full nuclear system digital twins of advanced reactors (e.g. MSR, HTGR, liquid metal, etc.) to reduce licensing timelines or improve performance.
- Minimizing proliferation, cyber, and security risks for nuclear technologies while maintaining affordability.
- Technologies that improve the performance and affordability of existing large light water reactors and advanced microreactors and small modular reactors, including approaches to enhance plant economics, output capacity, and longevity, as well as advanced construction techniques, autonomous control, robotics, and other innovations that reduce costs.
- Enhancing safety and reducing technical and regulatory risks.
- Analyzing and reducing manufacturing and construction costs for nuclear plants.

Not of Interest

Areas NOT of interest to this sub-topic:

- Entirely new micro and small modular reactor concepts.
- Activities not tailored for the nuclear power sector.

Topic 11: Fuel Cycle Research and Development (FCR&D)

The primary mission for the Office of Nuclear Energy is to advance nuclear energy science and technology to meet key energy resilience and economic needs in the United States. Proposed projects must demonstrate a strong tie to at least one of NE's three major goals: keeping existing U.S. nuclear reactors operating, deploying new nuclear reactors, and securing and sustaining nuclear fuel cycles.

This topic area targets the development of fuel cycle technologies. Applications are sought with special emphasis on bridging gaps between early-stage research and commercialization. By funding projects in the areas of interest below, NE aims to build a resilient, secure, highly

automated and economically competitive nuclear infrastructure for both the existing fleet and advanced reactors.

Areas of Interest

Areas of particular interest include, but are not limited to:

- Enhancing domestic nuclear fuel supply chain capabilities.
- Technologies that enhance fuel cycle safety and reduce technical and regulatory risk.
- Improving nuclear fuel resource utilization through advanced recovery and reuse technologies of valuable components from used nuclear fuel.
- Advancing technology readiness of nuclear fuels, cladding, and material compositions for current commercial light-water reactor (LWR), non-LWR, and advanced reactors. Key focus areas include, but are not limited to, metallic fuel forms, molten salt fuel, silicon carbide (SiC) cladding, and Tri-structural ISOtropic (TRISO) particle fuel.
- Technologies to reduce waste generation and volume of waste to be dispositioned.
- Limiting proliferation risk through materials control and accounting (MC&A) requirements.

Not of Interest

Areas NOT of interest to this sub-topic:

- Applications focused on border security, nuclear forensics, nuclear medicine, personnel dose monitoring, or nuclear weapons.
- Applications that fail to justify the use of surrogate materials for fuel fabrication (<https://ammt.anl.gov/>).

Topic 12: Nuclear Energy Enabling Technologies (NEET)

The primary mission for the Office of Nuclear Energy is to advance nuclear energy science and technology to meet key energy resilience and economic needs in the United States. Proposed projects must demonstrate a strong tie to at least one of NE's three major goals: keeping existing U.S. nuclear reactors operating, deploying new nuclear reactors, and securing and sustaining nuclear fuel cycles.

To address the challenges facing the deployment of nuclear energy systems, this topic area targets the development of enabling and crosscutting nuclear energy technologies. Applications are sought with special emphasis on bridging gaps between early-stage research and commercialization. By funding projects in the areas of interest below, NE aims to build a resilient, secure, highly automated, and economically competitive nuclear infrastructure for both the existing fleet and advanced reactors.

Areas of Interest

- Demonstrating and deploying resilient and reliable advanced sensors, instrumentation, and control systems for existing and advanced reactors. (<https://asi.inl.gov/>). Some of these sensors and instrumentation may leverage novel physical phenomenon including quantum effects.
- Develop new, high-performance materials enabled by advanced manufacturing for nuclear energy applications.
- Enhancing domestic supply chain capabilities for sensors and materials.

- Advancements that apply NE's advanced modeling and simulation tools (<https://neams.inl.gov/code-descriptions/>) to industry problems or otherwise increase use of these tools by the nuclear industry.
- Development of industry-relevant novel post-irradiation examination tools or methods applicable to radiological materials and environments (e.g., hot cells) that support accelerated advanced reactors material qualification efforts or materials degradation testing for the existing LWR fleet.

Not of Interest

Molten salt spectroscopy applications and digital twins of full reactor systems should consider Topic 10: Reactor Concepts Research, Development and Demonstration.

Topic 13: Advanced Technologies for Used Nuclear Fuel and High-Level Waste Disposition

The Department of Energy (DOE) is committed to fulfilling its legal mandate under the Nuclear Waste Policy Act of 1982, as amended, to safely and securely manage, store, transport, and permanently dispose of the nation's commercial used nuclear fuel (UNF) and high-level radioactive waste (HLW). DOE's Nuclear Lifecycle Innovation Campuses (Campuses) initiative is a transformative effort to modernize the nuclear lifecycle, including disposition of UNF and HLW. DOE anticipates campus activities to integrate waste disposition systems with other components of the nuclear lifecycle. To advance this mission, this solicitation prioritizes small business innovations in three key areas:

Areas of Interest

- Advanced material and manufacturing technologies for standardized waste packages,
- Environmental modeling and predictability frameworks for concrete dry-storage overpacks, and
- Identification of new and novel approaches to meet regulatory licensing pathways for a Campus.

Goals and Metrics

To address these priorities, applicants are encouraged to propose innovative, scalable technologies that bridge the gap from laboratory-scale concepts to field-ready operations. Specific technical innovations of interest include the development of next-generation materials and advanced manufacturing techniques (such as advanced cladding, coatings, or additive components) to maximize canister/container durability and reduce lifecycle production costs. Additionally, there is a critical need for high-fidelity multi-physics modeling frameworks capable of predicting combined thermal, mechanical, chemical, and radiological degradation of reinforced concrete overpacks subjected to decades of environmental weathering and decay heat. Innovations are also sought in advanced site characterization and subsurface monitoring technologies—such as robust, high-temperature sensors and geophysical imaging techniques—designed to gather reliable geological data within crystalline, shale, or salt host rock environments. Finally, the new and novel regulatory innovations can leverage, for example, risk informed and performance-based approaches, probabilistic risk enhancements, and recent regulatory enhancements to *Title 10 of the Code of Federal Regulations* by the Nuclear

Regulatory Commission that are relevant to a Campus initiative and may result in a more streamlined and effective licensing pathway for facilities with a primary function of disposition of UNF and HLW. This topic incentivizes commercial-ready solutions that reduce federal liabilities, simplify transport logistical complexities, the potential to reduce overall costs and licensing timelines, and enhance safety margins during extended storage (greater than 100 years) prior to permanent geologic disposal.

Topic 14: Grid Innovations to Strengthen, Enhance and Expand the Electric System's Capacity, in a Cost Effective and Timely Manner

The Office of Electricity (OE) leads U.S. Department of Energy (DOE) efforts to ensure the affordability, reliability and security of the electrical grid. Securing energy dominance, cost-effectiveness, and national security is paramount, alongside driving the deployment of groundbreaking grid innovations. DOE is interested in innovative projects that will stabilize, optimize and grow the grid by enhancing reliability, affordability, security and system capacity through one or more of the areas of interest below.

Areas of Interest

- Cybersecurity, cyber resilient frameworks and architectures, secure grid communications, and grid supply chain security.
- Grid enhancing technologies, materials, components and operations tools and techniques, including solutions that improve the efficient use of grid infrastructure.
- Advanced Microgrid design, operations, control and monitoring technologies.
- Advanced stationary energy storage technology development—spanning energy storage materials, system-level architectures, battery safety & validation, and grid-tied integration tools.
- Analysis tools, techniques and capabilities that support and fast-track large load (e.g. data centers; manufacturing) interconnections.

Goals and Metrics

Applications submitted under this topic must explicitly articulate the merit of the proposed innovation relative to competing solutions (where applicable) and outline the anticipated and measurable metrics, outcomes and benefits, including how the proposed solution advances the state of the art. Applicants must justify and support any performance claims in order to sufficiently demonstrate the viability of the solution. Finally, applicants must justify the strong commercialization potential of their solution by detailing a viable pathway for scaling up in prospective Phase II and Phase III efforts. Proposed solutions must support the Office of Electricity's core vision of a seamless, resilient grid that satisfies all energy demands and powers the United States on a trajectory of prosperity, security, and energy dominance.

Additional considerations pertinent to this topic include Quantum- and SI-enabled approaches are eligible where they directly address the program office's mission and technical objectives.

Not of Interest

- Applications that are substantially duplicative of work already solicited or funded through DOE's Genesis Mission may be considered nonresponsive.

- Applications that include focus on non-dispatchable, intermittent generation are considered not of interest and will not be reviewed.

Reference

1. Office of Electricity Strategic Plan, U.S. Department of Energy (2024), <https://www.energy.gov/oe/office-electricity-strategic-plan>.

Chapter 2: Science Topics

Topic 15: Commercialization of ASCR/ECP-Funded Software

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 high-performance computing (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.

While many ASCR-supported software packages are open-source, they are often complicated to use, distributed primarily in source-code form targeting scientific 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 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.

Goals and Metrics

- Work proposed under this topic must critically depend on one or more software packages that has been funded through ASCR or through the Exascale Computing Project (ECP, 2016-2024, <https://www.exascaleproject.org/>). Applications should include a reference (web page or other citation) to show that the relevant software has been supported by ASCR or ECP. 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.
- **Super Intelligence:** DeepHyper (<https://deephyper.github.io/>), LBANN (<https://github.com/LLNL/lbann>). ASCR-funded software that enables an application to SI is in-scope even if it is not specific to SI.
- **Software for Quantum Computing and Information:** Proposed products stemming from ASCR-funded software and algorithms for quantum information science are in-scope. Examples of such software and algorithms include BQSKit (<https://bqskit.lbl.gov/>), the quantum compiler framework, Jaqal (<https://www.sandia.gov/quantum/quantum-information-sciences/projects/qscout-jaqal/>), the assembly language for trapped ion quantum computers, Superstaq (<https://inflection.com/quantum-software/>), quantum compilation and control tools, and QubiC (<https://gitlab.com/LBL-QubiC/software>), qubit control system.
See <https://science.osti.gov/ascr/Research/Quantum-Information-Science-QIS> for more information. ASCR-funded software that enables an application to quantum information is in-scope even if it is not specific to quantum information science.
- **Performance Tools:** HPCToolkit (<https://hpctoolkit.org>), PAPI (<https://icl.utk.edu/papi/>), Dyninst (<https://github.com/dyninst/>), TAU (<http://www.cs.uoregon.edu/research/tau/home.php>), Darshan (<https://www.mcs.anl.gov/research/projects/darshan/>).
- **Software maintained by the members of the Consortium for the Advancement of Scientific Software,** <https://cass.community/>.
- Software packages that have received ASCR funding as part of SciDAC (<https://www.scidac.gov/>) and other computational partnerships are also 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 package are out of scope.
- Applications are sought to take one or more ASCR-funded software packages and make them easier to use or to incorporate ASCR-funded libraries into existing or new commercial software packages, or some combination of these adaptations. Example projects could include adding new capabilities, providing graphical user interfaces, making APIs for additional programming languages, hardening codes, and offering user support. Successful applications will address the potential both to broaden audiences for ASCR-funded software and to contribute to its stewardship.
- 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, including through the timely correction of software defects. Accordingly, ASCR encourages contributing bug fixes, 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.

References

1. U.S. Department of Energy, *Software*, Scientific Discovery through Advanced Computing (SciDAC), U.S. Department of Energy, June 12, 2025, <https://www.scidac.gov/software-list.html>.
2. U.S. Department of Energy, *SciDAC Feature*, Scientific Discovery through Advanced Computing (SciDAC), U.S. Department of Energy, June 12, 2025, <http://www.scidac.gov>.
3. ECP, *ECP Software Technology Capability Assessment Report–Public*, ECP-RPT-ST-0002-2020-Public, February 2020, <https://www.exascaleproject.org/wp-content/uploads/2020/02/ECP-ST-CAR-V20-1.pdf>.
4. U.S. Department of Energy, *Exascale Computing Project*, June 12, 2025, <https://www.exascaleproject.org/>.
5. U.S. Department of Energy, Office of Scientific and Technical Information, *DOE CODE*, June 12, 2025, <https://www.osti.gov/doecode/>.
6. Jenny Servo, *Market Research Study: Applications of ASCR HPC Software*, 2022, <https://www.osti.gov/biblio/1874151/>.

Topic 16: Cybersecurity for Scientific High-Performance Computing

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 high-performance computing (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 processors 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 HPC 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.

Goals and Metrics

- 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.
- 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 and must include an estimate of the performance overhead that will be introduced on target HPC workloads. Performance means the average execution time over the HPC target workloads specified in the narrative.
- This topic area seeks tools or technologies to strengthen isolation of distinct jobs running on the same HPC node. Proposed solutions must improve user or project isolation, specifically in the context of either the HPC scheduler or the HPC filesystem. This could include, but is not limited to, a tool or technology that ensures 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, as well as isolation of distinct jobs running simultaneously on a shared node.
- This topic area also seeks SI-enabled tools or technologies that improve the observability of HPC system-level operations by 1) revealing anomalous behavior at the

system-level and 2) distinguishing anomalous behaviors that are legitimate although unexpected, from those that indicate malicious compromise. The SI tool or technology can be tailored to one or more of the zones – high-performance computing, data storage, access, and management – that comprise the HPC system reference architecture as described in the NIST Special Publication NIST SP 800 223 (Reference 1). It can be developed for runtime use or for offline static analysis, or both. This could include, but is not limited to, an SI tool or technology that analyzes the aggregated behavior of individual HPC constituent components such as, but not limited to, processors, nodes, interconnects, and distributed file systems, to reveal larger patterns of malicious behavior at the HPC system-level that may not be apparent at the individual component-level.

Not of Interest

Proposed work is out of scope that: fails to identify target HPC workloads and provide an estimate of the performance overhead on those workloads; or is estimated to impede performance on HPC target workloads by more than 3%; or does not specifically address HPC systems or component technology unique to HPC platforms.

References

1. National Institute of Standards and Technology, *High Performance Computing (HPC) Security: Architectures, Threat Analysis and Security Posture*, NIST Special Publication 800-223, 2024, <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-223.pdf>.
2. National Institute of Standards and Technology, *High-Performance Computing (HPC) Security Overlay*, NIST Special Publication 800-234, 2026, <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-234.pdf>.
3. U.S. Department of Energy, Office of Science, *ASCR Cybersecurity for Scientific Computing Integrity*, DOE Workshop Report, 2015, <https://www.energy.gov/sites/default/files/2015/08/f25/ASCR%20Cybersecurity%20for%20Scientific%20Computing%20Integrity%20Workshop%20Report.pdf>.
4. National Academies Press, *Cyber Hard Problems: Focused Steps Toward a Resilient Digital Future*, 2025, <https://nap.nationalacademies.org/catalog/12345/cyber-hard-problems-focused-steps-toward-a-resilient-digital-future>.

Topic 17: Novel Instrumentation for X-ray and Neutron Facilities

The Basic Energy Sciences (BES) program invites applications for development of technologies to support its X-ray and neutron scattering scientific user facilities and advance BES missions in designing and building next-generation facilities. As science-driven X-ray and Neutron beam performance requirements increase, new technologies in accelerators, optics, instrumentation, and detectors are needed to generate, shape, and use these beams.

Areas of Interest

Specific areas of interest include the following:

- a. **Permanent magnet-based accelerator elements:** A promising future upgrade path for DOE BES light sources and accelerator facilities is a new “Complex Bend” (CB) lattice that requires combined-function permanent magnet quadrupoles (PMQs). These PMQs integrate both bending (dipole) and strong focusing (quadrupole) magnetic fields within a single

magnet assembly. Their compact design saves longitudinal space, addressing a common constraint in low-emittance lattice design.

Goals and Metrics

- The magnetic field strength requirements for these combined-function magnets are 0.5 Tesla for the dipole component and 130 Tesla per meter (T/m) for the quadrupole component. Additionally, the magnetic field must maintain a low level of higher-order multipoles (harmonics), specified as 10 units (1000 ppm) within a 3 mm good field region. Meeting this requirement is particularly challenging given the small magnet aperture (16 mm diameter), which increases sensitivity to mechanical and magnetic material errors.
- Proposals are sought for the development of two types of combined-function permanent magnet quadrupoles (PMQs):
 - A hybrid PMQ design that combines PM with soft iron pole materials.
 - A Halbach-type PMQ that uses only PM and offers more compact design geometry than the hybrid design.
- Further research and development (R&D) are needed to address key challenges associated with both designs and to meet the following requirements:
 - Magnetic field correction after assembly
 - Tunability of the magnetic field ($\pm 2\%$)
 - Precise alignment within 15 μm
 - Enhanced radiation resistance of permanent magnet materials enabling a lifecycle exceeding 30 years

References

1. Halbach, K., *Design of Permanent Multipole Magnets with Oriented Rare Earth Cobalt Materials*, Nuclear Instruments and Methods, vol. 169, p. 1, 1980. Available at [https://doi.org/10.1016/0029-554X\(80\)90094-4](https://doi.org/10.1016/0029-554X(80)90094-4).
2. Shaftan, T., Smaluk, V., and Wang, G., *The Concept of Complex Bend*, Brookhaven National Laboratory, NSLS-II Tech Note 276, 2018. Available at <https://technotes.bnl.gov/PDF?publicationId=211211>.
3. Brooks, S., et al., *Permanent Magnets for the Return Loop of the Cornell-Brookhaven Energy Recovery Linac Test Accelerator*, Physical Review Accelerators and Beams, vol. 23, 112401, 2020. Available at <https://doi.org/10.1103/PhysRevAccelBeams.23.112401>.
4. N'Gotta, P., et al., *Hybrid High Gradient Permanent Magnet Quadrupole*, Physical Review Accelerators and Beams, vol. 19, 122401, 2016. Available at <https://doi.org/10.1103/PhysRevAccelBeams.19.122401>.
5. N'Gotta, P., et al., *Development of Permanent Magnets Dipole-Quadrupole for NSLS-IIU*, Invited talk at Low Emittance Ring – Permanent Magnet Workshop, Trieste, Italy, November 14–15, 2023. Available at https://indico.cells.es/event/1373/contributions/2340/attachments/1631/3352/Low_Emittance_Ring_PM_Workshop_Ngotta.pptx.

b. *In situ* X-ray optics cleaning methods: An X-ray optical system typically consists of one or more mirrors or gratings housed in an ultra-high vacuum (UHV) chamber, along with in-vacuum and/or out-of-vacuum precision motion and mechanical systems. The optical and mechanical requirements for X-ray optics at diffraction-limited synchrotron light sources and free-electron laser facilities are extremely demanding, as they must preserve the source's wavefront and intensity. These optics are often made from single-crystal silicon, polished to a shape with sub-nanometer figure errors, and typically coated with transition metals and/or boron carbide to improve X-ray reflectivity and/or diffraction efficiency.

The fabrication, characterization, assembly, and installation of these X-ray optical systems are extremely challenging and costly due to the stringent requirements for cleanliness, precision, and stability. Unfortunately, carbonaceous buildup on the optical surfaces during operation is inevitable. This contamination worsens the figure error and, in turn, degrades the X-ray beam. An *in-situ* method for servicing these optics to restore their original high-quality figure is therefore required to reduce the effort for maintenance or performance recovery and minimize operational downtime.

Goals and Metrics

Proposals are sought for the design of an instrument/apparatus that applies a verified method for cleaning highly precise X-ray optics *in-situ* that meet the following criteria/requirements:

- The method must demonstrate the following properties:
 - Applicability for substrates made of common materials for X-ray optics, such as single crystal silicon and fused silica, up to 1 meter in length
 - Applicability to substrates with common coating thin-film materials, such as Au, Ru, Pt, SiC, B₄C, Mo/Si, and Ni. Note that cleaning different coatings may require different approaches. Approaches that can address multiple coatings are strongly encouraged.
 - Preservation of the quality and property of the polished surface, i.e., micro roughness and figure error, without oxidation and/or degradation of the optic mechanics, mounting components, or vacuum chamber
 - Permanent device installation, or on a per-cleaning-need on the vacuum chamber
 - Utilization of a non-toxic gas or cleaning agent that does not require special handling of the source gas or the exhaust gas
- The instrument/apparatus and cleaning method must be UHV compatible
- All necessary mechanics, electronics, and controls components must be provided as part of the design package.
- A proven and repeatable cleaning recipe for each type of addressable coating is provided with the method.

Note: Applicants are further encouraged to study literature in the following areas:

- Plasma Cleaning Techniques for synchrotron mirrors.
- Atomic Hydrogen Cleaning
- In-Situ Cleaning and Prevention
- Advanced Cleaning Technologies [as applied to Extreme Ultraviolet (EUV) lithography]
- Mirror Lifetime and Degradation Studies

References

1. Oxford University Press, *Coherent X-ray Optics*, D. Paganin, 2007, <https://academic.oup.com/book/doi/10.1093/acprof:oso/9780198528606.001.0001>.
2. *Carbon contamination of soft X-ray beamlines: dramatic anti-reflection coating effects observed in the 1 keV photon energy region*, C. Chauvet, F. Polack, M. G. Silly, B. Lagarde, M. Thomasset, et al., Journal of Synchrotron Radiation, vol. 18, p. 761, 2011. Available at <https://doi.org/10.1107/S0909049511023119>.

c. Strain-engineered optics for next-generation X-ray spectroscopy: X-ray spectroscopy is a critical tool for detailed characterization of advanced materials relevant to quantum information, chemical catalysis, and biological processes, particularly in the hard X-ray regime (~6 keV to 15 keV). A key limitation of current instruments is the trade-off between energy

resolution, measurement sensitivity, and instrument compactness [1,2], which limits their broader applicability and overall throughput. Throughput can be increased by enlarging the solid angle of collection, which is typically achieved by tiling many analyzers, resulting in bulky and high-maintenance spectrometers [3]. An alternative way to improve the solid angle is to reduce the distance between a sample and the crystal analyzer. This, in turn, requires the crystal to be bent to a correspondingly smaller radius of curvature (e.g., < 25 cm). However, tensile strain introduced by bending broadens the crystal's diffraction profile (i.e., the rocking curve), which degrades the instrument's energy resolution, negating the benefits of the increased solid angle.

Goals and Metrics

- Proposals are sought to develop innovative methods for actively controlling and compensating for bending-induced strain. The goal is to manage the diffractive properties of the crystal, allowing the use of small-radius analyzers while maintaining high energy resolution on the order of 100 meV or below at 10 keV, to achieve a ~30-fold enhancement in solid angle.
- Proposals should aim to create a net-zero or near-zero strain condition on the crystal's diffracting planes on the bent analyzers. The goal is to enable a new class of high-throughput, high-resolution hard X-ray spectrometers by overcoming the current limitations of bent crystal optics. These analyzers must integrate into existing systems and deliver enhanced spectral performance and collection efficiency through strain-engineered designs.

References

1. Sahle, C. J., Mirone, A., Niskanen, J., Inkinen, J., Krisch, M., and Huotari, S., Planning, performing and analyzing X-ray Raman scattering experiments, *Journal of Synchrotron Radiation*, vol. 22, p. 400, 2015, <https://doi.org/10.1107/s1600577514027581>.
2. Baron, A. Q. R., Introduction to High-Resolution Inelastic X-Ray Scattering, *arXiv preprint arXiv:1504.01098 [cond-mat.mtrl-sci]*, 2015, <https://arxiv.org/abs/1504.01098>.
3. Huotari, S., Sahle, C. J., Henriquet, C., Al-Zein, A., Martel, K., Simonelli, L., Verbeni, R., Gonzalez, H., Lagier, M. C., Ponchut, C., Moretti Sala, M., Krisch, M., and Monaco, G., A large-solid-angle X-ray Raman scattering spectrometer at ID20 of the European Synchrotron Radiation Facility, *Journal of Synchrotron Radiation*, vol. 24, p. 521, 2017, <https://doi.org/10.1107/s1600577516020579>.
4. Potential synchrotron beamlines include Stanford Synchrotron Radiation Lightsource (SSRL) 17-2, Advanced Photon Source (APS) 3-ID, and 1-BM.

d. Super Mirror Developments for Neutron Scattering Instrumentation: Proposals are sought to advance super-mirror coating technology for highly efficient reflection of thermal and cold neutrons at large incident angles. These nano-layer coatings are critical for maintaining and enhancing scattering instrumentation at national neutron sources to support materials science and engineering. The same techniques can be used to fabricate novel monochromator materials for energy selection.

Goals and Metrics

Proposals are sought in two areas:

- Super-mirror Coatings for Harsh Environments: To efficiently transport increased brightness from brighter sources, metallic substrates with high m -value coatings must be placed near moderated thermal and cold neutron sources.

- Reflectivity: Near-unity thermal neutron reflectivity (expectations: > 80% for a 2.0 Å neutron at grazing angle of 0.8 deg ($m = 4$)).
- Resilience: High thermal and radiation resilience to withstand harsh accelerator or reactor environments, with an operating lifetime of 5–15 years.
- Dimensions: Substrate thickness of 5–10 mm; minimum dimensions of 5 cm wide by 100 cm long.
- Novel Monochromator Developments: Development of bi-layer nano-composite structures to resolve thermal and cold neutron beam energies with higher efficiency and finer resolution.
 - Efficiency: Scattering efficiency > 80% of 1.5 Å neutrons with bandwidth ≤ 0.15 Å.
 - Polarization: If polarizing, polarization efficiency > 95% at 2.0 Å.

References

1. Saxena, A. M. and Schoenborn, B. P., "Multilayer neutron monochromators." Acta Cryst. A33, 805 (1977). International Union of Crystallography, Multilayer neutron monochromators, Acta Cryst. A33, 805 (1977), <https://doi.org/10.1107/S056773947700196X>.
2. Hayter, J. B. and Mook, H. A., "Discrete thin-film multilayer design for X-ray and neutron supermirrors." Journal of Applied Crystallography 22, 35 (1989). International Union of Crystallography, Discrete thin-film multilayer design for X-ray and neutron supermirrors, Journal of Applied Crystallography 22, 35 (1989), <https://doi.org/10.1107/S0021889888010003>.
3. Elsenhans, O., et al., "Development of Ni/Ti multilayer supermirrors for neutron optics," Thin Solid Films 246, 110 (1994). Elsevier, Development of Ni/Ti multilayer supermirrors for neutron optics, Thin Solid Films 246, 110 (1994), <https://www.sciencedirect.com/science/article/pii/0040609094903123>.
4. Instrument Development Beamlines at HFIR, Oak Ridge National Laboratory, <https://neutrons.ornl.gov/developmentbeamlines>.

e. High Rate and Low-Photon Sensitivity Neutron Area Detectors: Proposals are sought for next-generation neutron imaging detectors that deliver high count rates, broad fields of view, fine spatial resolution, and high-contrast discrimination between high-energy gammas and thermal/cold neutrons.

Goals and Metrics

- Specific requirements include:
 - Field of view as large as 30 cm x 30 cm in area.
 - Instantaneous Areal Counting Rate as high as 10 MHz/cm².
 - Spatial resolution as fine as 0.5 mm.
 - >70% efficiency at thermal neutron energies.
 - Photon rejection <10⁻⁶ at 2 MeV photon energy.
- Phase I projects must deliver a prototype using a minimal electronics subset tested to demonstrate performance expectations and clear scalability toward the final goal. Phase II will require a complete prototype meeting all performance specifications, demonstrated at a neutron facility capable of validating the high counting flux and photon rejection requirements.

References

1. C. Zhang and Z. Morgan, "Advanced Image Reconstruction for MCP Detector in Event Mode," in Communications in Computer and Information Science, vol. 1512, p. 383, 2022, available at https://doi.org/10.1007/978-3-030-96498-6_22.
2. A.S. Losko et al., "New perspectives for neutron imaging through advanced event-mode data acquisition," in Scientific Reports, vol. 11, p. 21360, 2021, available at <https://doi.org/10.1038/s41598-021-00822-5>.

Topic 18: Data, Synthesis, and Characterization Strategies for SI-Driven Materials and Molecular Systems Discovery

The Department of Energy's (DOE) Basic Energy Sciences (BES) program supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels. By focusing on the discovery of new materials and the design of new chemical processes, BES provides the essential foundations for innovative energy technologies. These research disciplines serve as a critical knowledge base and an agent of change, supporting vital DOE missions across energy, the environment, and national security to achieve a secure energy future.

Super intelligence (SI) and machine learning (ML) offer an opportunity to accelerate these discoveries by enabling researchers to uncover and integrate underlying chemical and physical principles across complex parameter spaces. This topic focuses on utilizing SI/ML to develop predictive frameworks and data-driven platforms that can guide the design, synthesis, and characterization of advanced materials and chemical processes. Achieving this ambitious goal requires first addressing the foundational challenge of managing the complex, heterogeneous data needed to train such predictive models. Therefore, this topic supports R&D that addresses the intertwined challenges of developing predictive frameworks and the data infrastructure required to enable them.

The BES program is seeking proposals that address the specific application area identified below, as well as enabling SI-powered data management frameworks. Proposals must explicitly address at least one of the goals below to be responsive to this topic, but applicants are encouraged to address both goals. A successful Phase I project should de-risk the core technical challenges, for example by demonstrating the successful ingestion of heterogeneous data into a prototype schema and showing a preliminary predictive relationship between that data and a key membrane property.

Areas of Interest

Specific areas of interest include the following:

a. SI/ML-Guided Molecular Membrane Development for CMM/REE Separations: The separation of critical minerals and materials (CMM) and rare-earth elements (REE) using organic or organometallic polymeric membranes typically relies on three fundamental mechanisms: (1) complexation of CMM or REE ions with extractants embedded in the membrane matrix, (2) adsorption of CMM or REE ions onto surface-active sites on a membrane, and (3) membrane rejection of CMM or REE ions or complexes utilizing organic functional groups. This topic seeks to optimize separation selectivity and extraction or rejection rates by leveraging SI for membrane synthesis, experimental design, and data analysis.

Goals and Metrics

- The overarching goal of this topic is to develop physical or hybrid data/physical models and design protocols that predict membrane structure and performance, supported by experimental validation of a selected subset of predicted structures. Successful projects must lead to hybrid physical/SI models that incorporate these fundamental mechanisms to design feasible, scalable membrane structures. These structures must be viable for large-scale processes and complex systems (e.g., mine tailings, reprocessed materials, seawater). Recent literature (see references 1 and 2) highlights opportunities to transition fundamental research into applied technologies for CMM and REE separation from complex solutions.
- Platform materials should consist of synthesizable organic or organometallic polymers functionalized to optimize selectivity, throughput, and stability. An SI supervisory algorithm should down-select candidate structures based on synthesizability and chemical stability in solution, utilizing empirical data from established structural families such as metal-organic frameworks (MOFs) and covalent-organic frameworks (COFs). Additionally, the models and design protocols must be extensible with the ability to identify parameters and features that distinguish between closely related structural families.

Not of Interest

Topics focused on engineering design, sensors, or routine synthesis and fabrication are excluded from this topic.

References

1. National Academies of Sciences, Engineering, and Medicine, Meeting Future U.S. Mineral Resource Needs: The Role of the U.S. Geological Survey Mineral Resources Program (The National Academies Press 2019), <https://doi.org/10.17226/29068>.
2. National Academies of Sciences, Engineering, and Medicine, A Research Agenda for Transforming Separation Science (The National Academies Press 2019), <https://doi.org/10.17226/25421>.

b. SI-Powered Data Management Platforms: Develop flexible, SI-enabled data platforms to support the synthesis and characterization workflows of molecular membranes structures described above.

Goals and Metrics

- The platform must be able to ingest and manage heterogeneous data types along with unstructured metadata.
- A highly desirable feature is the inclusion of SI-assisted tools for metadata population, such as parsing information from photos of lab notebooks or transcribing audio notes. The platform should provide a suite of standard machine learning analyses (e.g., clustering, embedding) and, most importantly, allow users to easily search, extract, and use the curated data to build targeted SI/ML applications.
- The final product is expected to adhere to FAIR (Findable, Accessible, Interoperable, and Reusable) data principles.
- Proposals seeking to develop a data management platform with a clear and direct application to a specific synthesis and characterization target application are strongly encouraged.

Topic 19: Enabling Technologies for Bioengineering and Quantum Science-Based Sensors

The U.S. DOE Office of Science Biological and Environmental Research (BER) program seeks to understand the basic biological, biogeochemical, environmental, and physical principles needed to fundamentally understand and predict processes found in nature occurring from the molecular to the global scale. Gaining a predictive understanding of these fundamental processes will help enable innovations in the design of new biosystems relevant to energy, chemical and materials production, new bioprocesses such as critical minerals and materials extraction and processing, and designing resilient crop production systems for a burgeoning bioeconomy. BER research also advances fundamental understanding of dynamic processes governing environmental systems through SI-driven and physical modeling coupled to field and process research to project impacts over time on crucial energy grid operation and infrastructure. This SBIR/STTR topic seeks projects focused on enabling technologies for quantum science-based sensors as well as enabling technologies to advance bioengineering. Projects should advance BER research and have commercial potential.

Areas of Interest

Specific areas of interest include the following topics.

a. Quantum sensing for atmospheric and terrestrial measurements: Taking advantage of quantum effects such as entanglement, superposition, interference, squeezed states, and coherence may improve resolution and detection limits, signal-to-noise ratio, and long-term signal stability of measurements compared to existing classical methods [1, 2, 3, 4, 5]. While there have been significant advances in quantum sensing measurement approaches in theoretical and laboratory settings [3, 4, 5], there are still many challenges in deploying quantum sensing technologies in real-world environments [6].

Goals and Metrics

- The objective of this priority area is to support the development and commercialization of new technologies that will enable the field deployment of robust quantum sensing instrumentation for atmospheric and terrestrial measurements under a wide range of environmental conditions.
- Applications are sought for innovative technologies that exploit quantum phenomena to surpass limitations of conventional methods for improved ground-based or airborne measurements of atmospheric or terrestrial properties relevant to BER research on land-atmosphere interactions. Properties relevant to this subtopic are those that provide information about the soil-plant-atmosphere continuum including moisture, heat, turbulence, and hydro-biogeochemical fluxes; evapotranspiration; vegetation composition; redox potential; biological volatile organic compounds; primary biological aerosol particles; and boundary-layer aerosol, cloud, and precipitation properties.
- Applications must focus on the development of quantum sensing technologies suitable for real-world, field-deployable instruments by considering factors such as sensitivity to environmental noise or vibration, measurement stability, calibration, error correction, duty-cycle, electromagnetic interference, decoherence, and power/weight.
- Applications may focus on hardening a quantum sensor to make it more suitable for inclusion in a field-deployable quantum sensing instrument, rather than developing a complete instrument, but must clearly explain how the proposed quantum component could eventually be utilized in a field-deployable instrument to improve measurements of one of properties of interest.

- Applications must indicate how the proposed quantum sensing technology would improve the measured accuracy, precision, detection limit, sensitivity, or other quality of the property of interest compared to existing conventional measurements.

References

1. Toward Quantum Enhanced Sensing and Measurements for Earth Observation in 2040, NASA Earth Science Technology Office Technical Interchange Meeting, NASA, Aug. 2024, https://esto.nasa.gov/files/NASA-QuantumSensing-TM_Report-Final.pdf.
2. Liu, H., Qin, C., Papangelakis, G., et al., "Compact all-fiber quantum-inspired LiDAR with over 100 dB noise rejection and single photon sensitivity," Nat. Commun., vol. 14, p. 5344, 2023, <https://doi.org/10.1038/s41467-023-40914-6>.
3. Dalvit, D. A. R., et al., "Quantum frequency combs with path identity for quantum remote sensing," Phys. Rev. X, vol. 14, p. 041058, 2024.
4. Wang, J., Wong, K. M., "Quantum illumination radars: Target detection," IET Radar Sonar Navig., vol. 18, no. 9, pp. 1541–1553, 2024, <https://doi.org/10.1049/rsn2.12592>.
5. Torromé, R. G. and S. Barzanjeh, "Advances in quantum radar and quantum LiDAR," Prog. Quantum Electron., vol. 93, p. 100497, 2024, <https://doi.org/10.1016/j.pquantelec.2023.100497>.
6. Bringing Quantum Sensors to Fruition, Subcommittee on Quantum Information Science, Committee on Science, National Science and Technology Council, Mar. 2022, <https://www.quantum.gov/wp-content/uploads/2022/03/BringingQuantumSensorsToFruition.pdf>.

- b. Quantum Enabled Bioimaging and Sensing Approaches for Biological Systems:** BER Bioimaging science program supports integrative approaches to detect, visualize, and measure biological processes *in situ* to gain a predictive understanding of cellular function. The program focuses on development of new imaging instrumentation and technologies for study of cellular and molecular systems and networks critical to research DOE-relevant plants, microbes, and microbial communities. Applications are invited that employ innovative, use-inspired approaches for quantum-enabled bioimaging and sensing to facilitate commercialization of these technologies [1, 2, 3].

Goals and Metrics

- The approaches should exploit quantum phenomena to surpass limitations of classical optics and propose a comparative advantage over competing classical optical methods.
- Applications can explore new quantum science-enabled light sources, imaging detectors or biosensors envisioned to overcome the current challenges of 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.
- Approaches can include quantum entanglement imaging combined with quantum science-based probes for sensing and measurement; quantum-based biosensors to detect other physical or chemical cues from the local biological environment and report conditions with photon emissions; and optical or other non-optical methods for quantum sensor signal readout including electromagnetic or particle detection.
- The development of new quantum science-enabled probes and sensors should be applicable for imaging of plant and microbial systems relevant to feedstocks for conversion to fuels, chemicals, and other bio-based materials and/or environmental research in BER. These quantum approaches and imaging systems need to visualize

plant and cellular structures and processes in a nondestructive manner, and at sufficient resolution to enable the validation of hypotheses of cellular function.

- Systems capable of measuring cellular dynamics *in vivo* are encouraged but not required.
- Imaging in two or three dimensions is emphasized while time varying measurements are desirable but not necessary in early-stage development. Research areas and processes of interest include probing biological systems to understand dynamic spatial and temporal relationships by characterizing structures of molecular and cellular components, chemical exchanges that facilitate the flow of information and materials across membranes and between intracellular partitions and measuring signaling processes between cells or organelles and plant-microbe and microbe-microbe interactions. Investigations at a larger scale can include the rhizosphere or whole plant responses to changing environments and within field settings. 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.

Not of Interest

Proposals focused only on computational studies are not in scope, but computational and super intelligence/machine learning (SI/ML) approaches for implementation and increased utility of the bioimaging approaches through integrated, automated and autonomous workflows would be of interest.

References

1. U.S. Department of Energy, DOE BER Market Research Study: Transitioning Quantum Imaging and Sensing Technologies to Bioimaging Markets (2022), https://science.osti.gov/-/media/sbir/pdf/Market-Research/DOE_QuantumSensorTechToMarket-071422.pdf (accessed June 26, 2024).
2. U.S. Department of Energy, Office of Science, Biological and Environmental Research, Quantum-Enabled Bioimaging and Sensing Approaches for Bioenergy (2021), <https://science.osti.gov/grants/FOAs/FOAs/2022/DE-FOA-0002603> (accessed June 26, 2024).
3. Subcommittee on Quantum Information Science, Committee on Science of the National Science & Technology Council, Bringing Quantum Sensors to Fruition (2022), <https://www.quantum.gov/wp-content/uploads/2022/03/BringingQuantumSensortoFruition.pdf> (accessed June 26, 2024).

c. Improving the Efficiency of Plant Regeneration and Nucleic Acid Delivery in Feedstock Crops Leveraging SI: This priority area seeks proposals to support the development and commercialization of new technologies that will improve the efficiency of plant regeneration and nucleic acid delivery (plant transformation) in bioenergy/feedstock crops (such as sorghum, switchgrass, miscanthus, populus, camelina, pennycress and energy cane) leveraging ML and SI.

Goals and Metrics

- Proposals should clearly indicate how the proposed methods will offer an improvement to or overcome barriers in the current methods.

- Qualifying technologies include but are not limited to developing predictive models to select optimal explants (starting material), improving selection of callus for regeneration, nucleic acid delivery and selection of transgenics, and using SI algorithms for developing optimal tissue culture conditions/protocols to ensure consistent and reproducible results and resource optimization.
- Applications should focus on design, development, and optimization at the lab scale.

Note: It is highly recommended that applicants discuss their technology with DOE to ensure fit prior to applying.

References

1. Albiol, J., Campmajó, C., Casas, C., & Poch, M., "Biomass estimation in plant cell cultures: a neural network approach," *Biotechnology Progress*, vol. 11, no. 1, pp. 88–92, 1995.
2. Alanagh, E.N., G-a, G., Haddad, R., Maleki, S., Landín, M., & Gallego, P.P., "Design of tissue culture media for efficient *Prunus* rootstock micropropagation using artificial intelligence models," *Plant Cell, Tissue and Organ Culture*, vol. 117, no. 3, pp. 349–359, 2014.
3. Arteta, T., Hameg, R., Landin, M., Gallego, P., & Barreal, M., "Neural networks models as decision-making tool for in vitro proliferation of hardy kiwi," *European Journal of Horticultural Science*, vol. 83, no. 4, pp. 259–265, 2018.
4. Hesami, M., & Jones, A.M.P., "Application of artificial intelligence models and optimization algorithms in plant cell and tissue culture," *Applied Microbiology and Biotechnology*, vol. 104, pp. 9449–9485, 2020.
5. Hesami, M., Condori-Apfata, J.A., Valderrama Valencia, M., et al., "Application of Artificial Neural Network for Modeling and Studying In Vitro Genotype-Independent Shoot Regeneration in Wheat," *Applied Sciences*, vol. 10, no. 15, p. 5370, 2020.

d. Complex Data: Advanced Data Analytic Technologies to Advance Bioengineering: BER 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 bioengineering applications. Technology improvements in biological instruments from sequencers to advanced imaging devices continue to advance at exponential rates, with data volumes in petabytes today that are expected to grow to exabytes in the future. These data are highly complex and include high throughput “omics” data, protein structure and imaging data, experimental and contextual environmental data across multiple scales of observations spanning molecular to cellular to multicellular scales within and among microbes and plants.

Goals and Metrics

- Innovative solutions and frameworks for management and analysis of large-scale, multimodal, and multiscale data and for correlating protein structural data with functional information leveraging SI/ML are needed. These include interoperable computational platforms to facilitate specialized data workflows starting from data collection, processing, access, sharing, integration, and analysis for large-scale, integrated omics, instrumental, and imaging datasets. Innovative, scalable solutions (e.g., software tools and modeling frameworks) capable of addressing the challenges of data management, integration, and analysis given the volume, complexity, and heterogeneity of big data are encouraged.

- Applications must indicate how the proposed solution demonstrates scalability and addresses key core areas, specifically the development of innovative methodologies and software for complex data management and interpretation to efficiently store, process, and interpret large-scale, high-dimensionality datasets.
- Additionally, proposals must offer robust frameworks for multi-modal data integration capable of unifying diverse, heterogeneous data types; this includes omics and phenotypic data, computational and chemical imaging in two and three dimensions (2D and 3D), and chemical communication pathways between organisms.
- Highly competitive proposals will feature generalizable data integration frameworks that enable researchers to generate testable hypotheses and construct predictive models of functional and causal connections across diverse systems.

Not of Interest

Applications that propose to develop space-based sensors or quantum communications techniques are out of scope. For bioimaging, 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 is excluded. Plant bioengineering applications must focus on non-food crops used as feedstocks for bioeconomy and supply chain resilience.

References

U.S. Department of Energy, *ASCR BER Exascale Requirements Review (GSP-Related Report)* (2016), <https://genomicscience.energy.gov/ascr-ber-exascale-requirements-review-gsp-related-report/> (accessed June 25, 2024).

Stacey, G. & Hungate, B.A., *Scientific User Research Facilities and Biological and Environmental Research: Review and Recommendations* (2018), https://science.osti.gov/-/media/ber/pdf/community-resources/2018/BERAC_UserFacilities_Report.pdf (accessed June 25, 2024).

U.S. Department of Energy, *DOE BER Biological Systems Science Division Strategic Plan* (2021), https://science.osti.gov/-/media/ber/pdf/bssd/BSSD_Strategic_Plan_2021_HR.pdf (accessed June 25, 2024).

U.S. Department of Energy, *Genomes to Structure and Function: Workshop Report 2022* (2022), <https://science.osti.gov/-/media/ber/pdf/workshop-reports/2023/Genomes-to-Structure-and-Function-Workshop-Report.pdf> (accessed June 25, 2024).

U.S. Department of Energy, *Artificial Intelligence and Machine Learning for Bioenergy Research: Opportunities and Challenges*, DOE/SC-0211, U.S. Department of Energy Office of Science and Office of Energy Efficiency and Renewable Energy (2022), <https://doi.org/10.2172/1968870> (accessed June 25, 2024).

Topic 20: Fusion Fuel Cycle and Enabling Technologies

The Department of Energy's (DOE) Fusion Energy Sciences (FES) program aims to resolve the scientific and technological gaps for a fusion pilot plant.

This topic targets innovations in the fusion fuel cycle and other cross-cutting enabling technologies that are critical for the sustainability, safety, and economic viability of future fusion energy systems. It is of paramount importance that applicants also assess how to optimally

implement nonproliferation, export control, waste disposal, accident scenarios, and community engagement for the fusion fuel cycle.

The scope encompasses the development of a safe, efficient, and reliable fusion fuel cycle, with a particular emphasis on deuterium-tritium (D-T) systems. This includes innovations in subcomponent technologies for fueling, exhaust processing, detritiation, material regeneration (e.g., getters, adsorbents), and tritium accountancy. These enabling technologies are crucial for accelerating the development of fusion systems and the supporting technologies required for eventual safe, economical operation.

Goals and Metrics

- **Fusion Fuel Cycle Innovation:** Develop and demonstrate key fuel cycle subsystems. Metrics include technologies capable of handling fusion-relevant fuel throughputs (e.g., kg/day), efficient detritiation techniques, ideally informed by techno-economic studies demonstrating a viable path to economic scaling. Requirements for reliability, availability, maintainability, and inspectability (RAMI) are of paramount importance as well. 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.
- **Integrated System Development:** Foster the integration of fuel cycle, control, and computational technologies. Metrics include demonstrating how innovations in one area can enable or optimize cost-effective, safe performance in another, contributing to a holistic fusion system design. Modeling of the fuel cycle based on existing open-source software and relevant supporting technologies is also included under this goal.

Not of Interest

- Topics mainly focused on physics (e.g., assembly, stability, confinement, heating, or sustainment) of fusion plasmas.
- Predominantly facility or test-stand design and/or construction.
- Concepts requiring net-energy-gain fusion and/or nuclear reactions at temperatures below 1 keV (aka “cold fusion” or “low-energy nuclear reactions”), except muon-catalyzed fusion.
- Work scopes that are not suited for integration into future fusion systems.
- Topics predominately focused on software development are specifically not of interest.

References

1. Electric Power Research Institute, *2024 Technical Update to the Fusion Fuel Cycles Research Objectives: Results from the 2023 Fusion Fuel Cycles Workshop*, 3002029371, Palo Alto, CA, 2024, <https://www.energy.gov/fusion/articles/epri-fusion-fuel-cycles-report-2024>.
2. *Fusion Science and Technology Roadmap*, U.S. Department of Energy, <https://www.energy.gov/fusion/fusion-energy>.

Topic 21: Advanced Particle and Radiation Detectors

The U.S. Department of Energy (DOE) Office of Science supports the development of next-generation particle and radiation detectors to drive discoveries in High Energy Physics (HEP) and Nuclear Physics (NP). Looking to the future planned facilities and upgrades—such as the

Electron-Ion Collider (EIC) second detector, High-Luminosity Large Hadron Collider (HL-LHC) upgrades, and rare event searches like next-generation dark matter and neutrinoless double-beta decay (NLDBD) experiments, to name a few examples—demand detector technologies that far exceed current state-of-the-art capabilities. Depending on the particular environment, these future experiments require some combination of unprecedented sensitivity, extreme radiation hardness, ultra-low radioactive backgrounds, and high-rate capabilities. This topic bridges the gap between laboratory-scale proof-of-concept designs and commercially viable detector components, supporting both the DOE's scientific mission and adjacent industrial, medical, and national security markets.

Areas of Interest

To address these future challenges, this topic seeks innovative proposals in three areas of interest.

a. Ultra-Low-Radioactivity Materials and Components: focusing on extremely radiopure structural, cabling, shielding, and low-temperature detector parts.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate understanding of the current state-of-the-art and offer innovative solutions to achieve or exceed targeted performance metrics:

- Develop superconducting cables with ^{238}U and ^{232}Th contamination limited to the parts-per-trillion level (ppt) and ^{40}K limited to parts-per-billion (ppb), with transition temperatures ($T_C > 2\text{ K}$ with above 4 K preferred) and parasitic resistance ($\sim\text{m}\Omega/\text{trace}$).
- Produce high-radiopurity structural components (e.g., nickel, tantalum, or titanium) with sub-ppt levels ^{238}U and ^{232}Th at thicknesses of 1 cm or more for structural or shielding applications.
- Develop radiopure electronic connectors with residual radioactivity $< 1\text{ ppt Th}^{238}\text{U}$ and ^{232}Th and $< 0.1\text{ mBq/kg}$ for metals (pure or alloys) though the exact requirements depend on the mass and location of the connectors with respect to the sensitive volumes of the experiment. In addition to radiopurity, the connectors must satisfy the specific electrical and thermal requirements (sensors typically operate at temperatures ranging from 165 K – 10 mK) specific to the particular detector.
- Develop gas getters exhibiting radon emanation ($< 0.1\text{ mBq }^{222}\text{Rn}$ in equilibrium for a gas flow capacity of > 1000 standard liters per minute).

b. High-Rate, High-Resolution Detectors and Scintillating Detector Materials: targeting next-generation focal plane spectrometers, Multigap Resistive Plate Chambers (MRPC), and fast-timing scintillating ceramics and glasses.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate understanding of the current state-of-the-art and offer innovative solutions to achieve or exceed targeted performance metrics:

- Develop next-generation heavy-ion focal plane detectors or integrated spectrometer systems with time resolution resolution ($< 150\text{ps FWHM}$), 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);

- Develop of Multigap Resistive Plate Chamber (MRPC) detectors with thin pressure windows for heavy-ion applications, aiming to achieve high-counting rates (≥ 200 kHz/cm²), high timing resolution (<50 ps) and resilience to radiation and magnetic fields.
- Develop large-volume (multi-m³), high-density (>6 g/cm³) scintillating ceramics or glasses (excluding single crystals) with light yields > 15,000 photons/MeV, decay times of tens of ns or less, and radiation hard (tens to hundreds of Mega-rad). To be of interest, a convincing case must be made that these materials will cost a few \$/cm³ once production methods are mature.

c. Vibration-Free Cryogenic Systems: emphasizing continuous, ultra-low-noise cooling and associated vibration monitoring at sub-Kelvin temperatures.

Goals and Metrics

- Develop continuous "dry" dilution refrigerators operating in a vibration-free (<10⁻⁷ g/sqrt(Hz) in the sub-Hz to 100 kHz range, with $g=9.81$ m/s²,) at temperatures around 10 milli-Kelvin and with cooling power of at least 0.5 milli-Watt at 100 milli-Kelvin.
- Develop calibrated sub-Kelvin accelerometer and readout systems with sensitivity at the level of 10⁻⁷ g/sqrt(Hz) or better below 0.1K, with self-heating limited to <1 micro-Watt at 10 milli-Kelvin that is capable of measuring mechanical vibrations directly at the coldest stages (below 0.1 Kelvin) of a dilution refrigerator.

Not of Interest

Proposed work is considered out of scope if it only offers incremental engineering advancements without a clear path toward high-impact commercialization or direct relevance to future HEP or NP programs. Scintillating crystals are not within the scope of this topic. General-purpose cryostats, sensors, or gas purification systems that do not meet the extreme radiopurity, vibration-free, or sub-Kelvin performance metrics specified above are ineligible. Standalone software developments or purely computational modeling efforts are also out of scope.

References

1. U.S. Department of Energy, 2023, *The 2023 Long Range Plan for Nuclear Science, A New Era of Discovery*, Office of Science. https://science.osti.gov/-/media/np/nsac/pdf/reports/2024/2024-NSAC-LRP-Report_Final.pdf.
2. U.S. Department of Energy, 2023, *Exploring the Quantum Universe: Pathways to Innovation and Discovery in Particle Physics* (aka 2023 P5 report), Office of Science. https://science.osti.gov/-/media/hep/pdf/2024/2023_P5_Report_Single_Pages.pdf.
3. Abdul Khalek R, et al., *Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report*. <https://inspirehep.net/literature/1851258>.
4. Coordinating Panel for Advanced Detectors (CPAD) Workshop 2024, University of Tennessee, Knoxville. <https://indico.phy.ornl.gov/event/510/>
5. Coordinating Panel for Advanced Detectors (CPAD) Workshop 2023, SLAC National Accelerator Laboratory. <https://indico.slac.stanford.edu/event/8288/>.

6. International Conference on Technology and Instrumentation in Particle Physics (TIPP 2023), Cape Town, South Africa. <https://indico.tlabs.ac.za/event/112/>.
7. Trento Workshop on Advanced Silicon Radiation Detectors (TREDI 2023), Trento, Italy. <https://indico.cern.ch/event/1223972/>.
8. DOE Basic Research Needs Study on High Energy Physics Detector Research and Development, 2020. <https://science.osti.gov/hep/Community-Resources/Reports>.

Topic 22: High-Performance Electronics and Data Acquisition Systems

The U.S. Department of Energy (DOE) Office of Science supports the development of advanced electronics and data acquisition (DAQ) systems to power discovery-scale experiments in High Energy Physics (HEP) and Nuclear Physics (NP). Future experiments at facilities like the Electron-Ion Collider (EIC), upgrades resulting in the High-Luminosity Large Hadron Collider (HL-LHC), and detectors used in deep-underground rare-decay searches—will generate immense, continuous data streams from tens of thousands of channels operating in extreme environments. To process this data, microelectronics must transition toward highly integrated, low-power Systems-on-Chip (SoCs), Application-Specific Integrated Circuits (ASICs), and robust DAQ architectures. These systems must deliver sub-picosecond timing, cope with cryogenic or high-radiation environments, and perform real-time, in-pixel data compression and filtering to mitigate downstream bandwidth bottlenecks.

Areas of Interest

To address these forward-looking challenges, this topic seeks innovative proposals in three priority areas.

a. Advanced Cryogenic and Superconducting Readout Microelectronics: focusing on ultra-low-power ASICs and superconducting digital signal processors for deep-cryogenic detectors such as transition edge sensors (TES), superconducting nanowire single photon detectors (SNSPD) arrays microwave kinetic inductance detectors (MKIDs).

Goals and Metrics

Proposals must address specific technical challenges and demonstrate understanding of the current state-of-the-art and offer innovative solutions to achieve or exceed targeted performance metrics:

- Develop superconducting microelectronics or ASICs operating at 4 K or below, possibly operating in magnetic fields of ~ 1 T, with per-channel power dissipation < 1 mW/ch large analog bandwidth > 1 GHz with 16 bits of resolution (minimum 14 ENOB after accounting for integral and differential nonlinearities) and high channel count (64 channels). Total power dissipation of the entire Application-Specific Integrated Circuit (ASIC) must not exceed 150 mW. The chip control and data interface should be compatible with commercial auxiliary electronics.
- Develop superconducting passive, heterogeneous bipolar, and active components integrated into functional circuits and systems, such as superconducting logic gates, oscillators, filters, and analog-/time-to-digital converters. Also of interest are low-noise cryogenic amplifiers (such as HEMT, SQUID, or parametric devices) optimized for the 4-8 GHz range, yielding a noise temperature < 4 K and input-referred third-order intercept point (IIP3) > -20 dBmW.

b. Radiation-Tolerant, High-Granularity Front-End ASICs: targeting Monolithic Active Pixel Sensors (MAPS) and Low Gain Avalanche Diode (LGAD) readouts with picosecond-level resolution and on-chip data processing.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate understanding of the current state-of-the-art and offer innovative solutions to achieve or exceed targeted performance metrics:

- Develop mixed-signal ASICs for detectors such as MAPS, Skipper-in-CMOS and LGADs with integrated charge collection on high-resistivity substrates ($>1 \text{ k}\Omega\cdot\text{cm}$), fully depleted over 5–20 μm thicknesses, and achieve charge collection within 20 ns. These ASICs should be radiation tolerant to at least $1\times 10^{15} \text{ neq/cm}^2$ where required.

c. High-Throughput Streaming DAQ and Real-Time Edge Processing: emphasizing reconfigurable filtering, on-chip machine learning engines, and high-bandwidth optical/electrical data links.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate understanding of the current state-of-the-art and offer innovative solutions to achieve or exceed targeted performance metrics:

- Develop mixed signal, high-speed ADC converters ($>12 \text{ ENOB}$, $>500 \text{ MSps}$) with per-channel signal conditioning and integrated on-chip FIR/IIR filtering for baseline stabilization, crosstalk correction, common mode tracking, and adjacent-channel crosstalk correction. The inclusion of an in-channel machine learning (ML) engine capable of nonlinear filtering, pulse classification based on waveform templates, feature extraction (pulse amplitude and timing parameter estimation), and streaming readout is particularly desired to reduce raw data rates directly at the front end.

Not of Interest

Proposed work is considered out of scope if it only offers incremental engineering advancements without a path toward commercialization or direct relevance to future HEP or NP programs. Development and testing of cryogenic Complementary Metal-Oxide-Semiconductor (CMOS) Application-Specific Integrated Circuits (ASICs) are excluded. Diamond-based sensor substrates are excluded. Standalone software developments or purely computational modeling efforts are also out of scope.

References

1. U.S. Department of Energy, 2023, *The 2023 Long Range Plan for Nuclear Science, A New Era of Discovery*, Office of Science. https://science.osti.gov/-/media/np/nsac/pdf/reports/2024/2024-NSAC-LRP-Report_Final.pdf.
2. U.S. Department of Energy, 2023, *Exploring the Quantum Universe: Pathways to Innovation and Discovery in Particle Physics* (aka 2023 P5 report), Office of Science. https://science.osti.gov/-/media/hep/pdf/2024/2023_P5_Report_Single_Pages.pdf.
3. Topical Workshop on Electronics for Particle Physics (TWEPP 2024), Indico, Glasgow, United Kingdom. <https://indico.cern.ch/event/1381495/>.

4. 12th International Meeting on Front-End Electronics (FEE 2023), Torino, Italy. <https://agenda.infn.it/event/36206/>.
5. Coordinating Panel for Advanced Detectors (CPAD) Workshop 2024, University of Tennessee, Knoxville (2024), <https://indico.phy.ornl.gov/event/510/>.
6. 23rd IEEE Real-Time Conference (RT 2022), Indico, CERN, Online (2022), <https://indico.cern.ch/event/1109460/>.
8. U.S. Department of Energy, DOE Basic Research Needs Study on High Energy Physics Detector Research and Development (2020), <https://science.osti.gov/hep/Community-Resources/Reports>.
9. Chou, A., et al., Quantum Sensors for High Energy Physics, Workshop Report, arXiv:2311.01930 (2023), <https://arxiv.org/abs/2311.01930>.
10. 1st International Workshop on a 2nd Detector for the EIC (2023), Brookhaven National Laboratory (2023), <https://indico.bnl.gov/event/18414/>.
11. Streaming Readout Workshop XIII (2025), Catania, Italy (2025), <https://agenda.infn.it/event/47630/>.

Topic 23: Multi-office SC topic - Innovative Accelerator Science and Technology

The U.S. Department of Energy (DOE) Office of Science supports the operation, upgrade, and stewardship of national particle accelerator scientific user facilities [1]. These facilities are critical for driving discoveries across [Basic Energy Sciences](#) (BES) [2], [High Energy Physics](#) (HEP) [5,6], and [Nuclear Physics](#) (NP) [8]. To keep pace with the demanding scientific requirements of fixed-target facilities, next-generation colliders, light sources, and neutron sources; accelerator technology must evolve to be more efficient, compact, and cost-effective. This topic integrates breakthroughs in superconductor materials, magnet engineering, radio frequency (RF) designs, laser drivers, advanced diagnostics, photocathodes, and ultrafast laser technology into a unified R&D pipeline that measurably advance the state of the art (SOTA) in accelerator technologies [9–11]. The goal is to transition high-risk, high-reward laboratory prototypes into commercially viable products that support both the DOE's research facilities and adjacent industrial, medical, and national security markets.

Areas of Interest

To address these challenges, this topic seeks innovative solutions aligned with the following five priority areas.

a. High-Field Superconducting Magnets and Advanced Conductor Materials, focusing on high-temperature superconducting (HTS) wire and tape fabrication alongside cryogenic powering.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate compliance with targeted performance metrics:

- Develop high temperature superconductor (HTS) wires capable of high field usage (>18 T) with $J_e \geq 400$ A/mm² at 20 T and 4.2 K over continuous lengths ≥ 1 km.
- HTS tapes must maintain I_c uniformity within $\pm 5\%$ over ≥ 75 m. HTS thin film conductors must exceed $J_c \geq 2$ MA/cm² at 77 K[4,5].

b. Compact, Combined-Function Magnetic Elements, targeting high-precision permanent magnets for low-emittance lattices and beam transport.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate compliance with targeted performance metrics:

- Develop combined-function permanent magnet quadrupoles (PMQs) for “Complex Bends” [3] for BES light sources that have a ≥ 0.5 T dipole and ≥ 130 T/m gradient in a ≥ 16 mm aperture with a multipole content $\leq 0.1\%$ in a ≥ 3 mm good field region.
- PMQs must meet: magnetic center alignment within 15 microns, 30-year radiation stability, and field quality ≤ 1000 ppm in a ≥ 3 mm good field region, with $\pm 2\%$ tuning range.

b. High-Efficiency RF Power Sources and Tunable Cavity Technologies, emphasizing cost-effective RF amplifiers, solid-state pulsers, and tunable superconducting radio frequency (SRF) systems.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate compliance with targeted performance metrics:

- Develop RF sources with $\geq 50\%$ (SSPAs) or $\geq 70\%$ (VEDs) efficiency, costing < 2 \$/W[6]. Kicker pulsers systems producing ≥ 20 kV, $\geq 1,000$ A, and 100–200 ns rise times.
- Tunable SRF cavities supporting a 1% tuning range and in-situ particulate cleaning.

c. Advanced Sources and Laser Driver Systems, focusing on high-brightness, high-quantum-efficiency photocathodes and high-average-power ultrafast laser systems.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate compliance with targeted performance metrics:

- Produce high brightness unpolarized photocathodes with MTE ≤ 30 meV (at 100 pC) for relevant applications, e.g., BES light sources.
- Produce high bunch charge polarized photocathodes producing ~ 1 -10 mA cw beams, or low rep rate polarized electron sources with bunch charges > 10 nC longitudinally polarized greater than 90% and quantum efficiency $> 2\%$ at ~ 780 nm for NP facilities[8].
- Develop ultrafast (≤ 1 ps) target driver lasers producing kilowatt-class power, Strehl > 0.95 , at ≥ 10 –20% power efficiency for driving photoemission electron sources, pump-probe experiments, and parametric sources of MWIR and LWIR[7].

d. Innovations in Accelerator Diagnostics: targeting higher performance, lower cost, and new capabilities for measuring charged particle beams.

Goals and Metrics

Proposals must address specific technical challenges and demonstrate compliance with targeted performance metrics:

- Innovations in Accelerator Diagnostics: Develop accelerators diagnostics with improved resolution, speed, and intelligence, including
 - (1) non-intercepting high precision current measurement in the 10 nA–100 μ A range (100 ppm accuracy),
 - (2) measuring stored Ampere-class beams,
 - (3) non-intercepting emittance measurement of 100 kW-class ion beams,

- (4) high sensitivity ion beam diagnostics for $1\text{E}2\text{--}1\text{E}7$ nuclei/s range at low (25–1000 keV/N) energies,
- (5) fast recovery (<1 ms) multipulse diagnostics for measuring interleaved ion beams with >40 dB intensity range, and (6) very fast (<10 us) beam loss detectors[8].
- Intelligent diagnostics capable of auto calibration, ranging, denoising, data analysis and reduction, and self-protection are strongly encouraged.
- Diagnostics incorporating electronics must be rad-hard to be suitable for accelerator use.

Not of Interest

Proposed work is considered out of scope if it only offers incremental engineering advancements without a clear path toward high-impact commercialization or direct relevance to BES, HEP, or NP programs. General-purpose RF sources, lasers, or power supplies that are not usable in accelerator facilities (because they lack key properties such as phase locking, ultra-low phase noise, or pulse formatting) or do not demonstrably advance the SOTA are ineligible.

References

1. DOE Office of Science User Facilities at a Glance, U.S. Department of Energy, <https://science.osti.gov/User-Facilities/User-Facilities-at-a-Glance>.
2. U.S. Department of Energy, *DOE BES Future Electron Sources Workshop*, Wang, X., Musumeci, P., et al., 2017, https://science.osti.gov/-/media/bes/pdf/reports/2017/Future_Electron_Source_Worskho%09p_Report.pdf?la=en&hash=9EC02151ABEA24A874721C557D0AA77ECC472E91.
3. Brookhaven National Laboratory, *The Concept of Complex Bend*, NSLS-II Tech Note 276, Shaftan, T., Smaluk, V., and Wang, G., 2018, <https://technotes.bnl.gov/PDF?publicationId=211211>.
4. Kesgin, I., Kasa, M., Ivanyushenkov, Y., Welp, U., 2017. *High-temperature superconducting undulator magnets*, Superconductor Science and Technology, vol. 30, 04LT01, <https://iopscience.iop.org/article/10.1088/1361-6668/aa5d48>.
5. *U.S. Magnet Development Program Roadmap*, U.S. Department of Energy, <https://science.osti.gov/-/media/hep/pdf/Reports/2020/USMDP-2020-Plan-Update-web.pdf>.
6. *RF Accelerator R&D Strategy Roadmap*, U.S. Department of Energy, https://science.osti.gov/-/media/hep/pdf/Reports/DOE_HEP_GARD_RF_Research_Roadmap_Report.pdf.
7. *Basic Research Needs Workshop on Laser Technology*, U.S. Department of Energy, https://science.osti.gov/-/media/ardap/pdf/2024/laser-technology-workshop-report_20240105_final.pdf.
8. *2023 Long Range Plan for Nuclear Science, A New Era of Discovery*, Office of Science, U.S. Department of Energy, https://science.osti.gov/-/media/np/nsac/pdf/reports/2024/2024-NSAC-LRP-Report_Final.pdf.
9. Riken Nishina Center, *22nd International Conference on Radio-Frequency Superconductivity (SRF 2025)*, 2025, <https://ribf.riken.jp/SRF2025/>.
10. Institute of Electrical and Electronics Engineers, *6th North American Particle Accelerator Conference (NAPAC 2025)*, 2025, https://proceedings.jacow.org/napac2025/pdf/napac2025_proceedings_volume.pdf.
11. International Particle Accelerator Conference, *17th International Particle Accelerator Conference (IPAC 2026)*, 2026, https://www.ipac26.org/prepress/pdf/ipac-26_proceedings_volume.pdf.

Chapter 3: National Nuclear Security Administration (NNSA) Topics

Topic 24: Proliferation Detection

The Office of Proliferation Detection within the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development office, develops novel technologies within two broad topics; near and remote, single or multimodal detection systems for detecting, locating, and characterizing nuclear activities and facilities; technologies that reduce reliance on high-activity medical and industrial radioactive sources in support of the Office of Global Material Security and other U.S. Government agencies.

Areas of Interest

Applications are of interest in the following areas:

- a. **Demonstration of a High-Intensity Entangled Photon Light Source for Remote Sensing:** The integration of quantum photonic devices into remote sensing platforms offers substantial advantages including scalability, compact footprint, high stability, and increased nonlinear interaction efficiency [1]. There are several quantum-based detection technologies that can be applied to remote sensing [2]. Science teams should try to minimize size, weight, and power of the source in design choices. Analysis showing potential capability of a high-intensity entangled light source toward these areas of improvement is also of interest.
- b. **Maritime, Limnologic, and Oceanic Hyperspectral Imagery Analysis Advancement:** The maritime shipping industry is considering deployment of nuclear-powered vessels to reduce carbon dioxide emissions [3]. The nuclear nonproliferation community has an interest in ensuring the safe deployment and use of such vessels via remote sensing [4]. Hyperspectral imagery can be implemented to assist nuclear power monitoring agencies for surface and subsurface environments [5]. Hyperspectral imagery data collected over bodies of water present unique analysis challenges [6]. This topic is an opportunity for development of advanced atmospheric correction methods that could include but are not limited to: 1) optimization of multimodal fusion that include SAR, multi/hyper spectral imagery, LiDAR, bathymetry, and other data modes, 2) investigation of few-shot learning with regard to absorbing aerosols, identification of interference from bottom reflections, cloud absorption, light scattering in water, and absorption of other gases and or materials of interest with the goal of understanding whether new signal types can be recognized from a handful of examples, 3) algorithm development for understanding the limits of underwater object identification including the maximum detectable depth under varying water types, the most useful spectral bands for surface and subsurface detection, best way to separate maritime constituents, and whether adaptive wavelength selection can improve detection, 4) improving reliability atmospheric correction over oceans, 5) Analysis techniques in the near infrared, visible, and ultraviolet portions of the spectrum are of interest. Analysis workflow development should also be considered. Typical data collection can be on the order of 100s of GB of data. Attention should be given to efficient edge processing of hyperspectral data cubes to maximize analysis workflow efficiency.
- c. **Radiation Detection Technologies:**
 - A compact, rugged, low-power, dual-mode gamma/neutron detectors for autonomous detection and characterization of special nuclear material, including highly

enriched uranium and plutonium, at ranges up to 10 meters in uncontrolled environments. Solutions should combine advanced scintillators, such as CLYC or CLLBC, with silicon photomultiplier readouts, multiplexed architectures, and embedded processing for real-time spectroscopy, neutron/gamma pulse-shape discrimination, and isotopic classification [7-10]. Algorithms must be validated using Monte Carlo simulations and calibrated-source testing. Prototypes should target the following performance objectives: $\leq 4\%$ gamma resolution at 662 keV, PSD figure of merit > 3 , thermal-neutron efficiency $\geq 10\%$, operational power ≤ 500 mW, mass ≤ 600 g, 72-hour endurance, passive thermal management, encrypted burst communications, low signatures, and MIL-STD-810H survivability from -40°C to $+65^{\circ}\text{C}$. Phase I should demonstrate feasibility through bench prototypes, embedded algorithms, simulations, and experimental characterization; Phase II should deliver an integrated qualified prototype, environmental testing, blind SNM trials, and a TRL-5 transition plan.

- A stationary, low-SWaP radiation detection and data-fusion system that unobtrusively localizes, identifies, and quantifies radiological and nuclear materials in vehicles traveling 5–65 mph. Solutions should exceed conventional presence alarms by mapping radiation measurements to a vehicle's three-dimensional structure, locating single or multiple sources, and providing real-time isotopic identification and activity estimates despite shielding, variable geometry, motion, standoff, NORM, and changing backgrounds [11-13]. Approaches may combine advanced detector architectures, algorithms, and auxiliary sensors such as LiDAR, machine vision, or radar. Systems should support low-latency edge processing, unattended or lightly attended operation, environmental robustness, minimal operator burden, and low operational signatures at checkpoints, crossings, weigh stations, or remote sites. Phase I should establish feasibility through modeling, simulation, or surrogate-vehicle testing and quantify localization, identification, activity-estimation, false-alarm, runtime, and latency performance. Deliverables include a technical report, proof-of-concept demonstration, and Phase II plan. Phase II will develop and field-test an integrated prototype under realistic scenarios.

d. Radiological Source Replacement Technologies:

- Innovative modeling and simulation solutions to improve dosimetry accuracy, safety, consistency, and standardization in radiation biology and preclinical research. Current practices rely heavily on high-activity gamma sources and traditional X-ray cabinets, which present safety risks, dose-delivery errors, biological variability, and inconsistent reporting [14-19]. Proposed approaches should integrate Monte Carlo methods, super intelligence, and machine learning to improve dose modeling, reduce reliance on gamma sources, optimize dosimeter placement, validate radiation fields, account for beam quality and sample geometry, and enable conversion from air kerma to absorbed dose. Solutions should support virtual testing, cross-modality dose comparisons, safer adoption of medium-energy X-ray irradiators, and reliable characterization of dose uniformity. Proposals may also address the development and validation of anatomically accurate, tissue-equivalent phantoms and methods to reduce interlaboratory discrepancies. The goal is precise, reproducible dose delivery—ideally within 5% of prescribed levels—and improved dosimetry practices across radiation research.
- A compact, vehicle-transportable, non-radioisotopic neutron generator to replace aging and restricted Cf-252, AmBe, and similar sources used for detector calibration and nondestructive assay. The system should provide safe, reliable, on-demand operation without the radiological, security, logistical, and availability challenges of isotope-based calibrators. It must produce an output approaching 200 mrem/hr at 50 cm—comparable

to a 20 Ci AmBe source—while offering moderated and beam-shaped neutron spectra representative of AmBe, Cf-252, and related sources [20]. Total power consumption should remain below 10 kW, with readily controllable activation and shutdown for improved safety and operational flexibility. Proposals should address innovative neutron-generation, moderation, and beam-shaping approaches capable of delivering compact, controllable, AmBe-equivalent performance. Successful solutions will enable more flexible calibration and NDA operations while reducing the hazards, regulatory burdens, and lifecycle costs associated with radioactive neutron sources.

- A highly mobile, rugged, and cost-competitive ultrasonic testing system capable of replacing radioisotope-based industrial radiography and reducing the security risks associated with Ir-192, Co-60, and Se-75 sources. The system should inspect pipes, boilers, and structural components in harsh environments, including cold conditions where conventional coupling fluids fail [21]. Proposals should develop innovative ultrasonic methods for detecting difficult defects, including narrow flaws aligned with the sound path, shallow surface cracks, and porosity variations. Advanced analysis software should simplify scan interpretation and reduce technician training requirements. Successful solutions must demonstrate reliable, durable, field-ready operation while providing performance comparable to gamma radiography and eliminating the need for high-activity radioactive sources.

References

1. Shi, M., Ming, S., Wu, S., et al., Quantum remote sensing with atom-light entangled interface, *Quantum Front.*, vol. 1, p. 17, 2022, available at <https://doi.org/10.1007/s44214-022-00020-y>.
2. Ryan, D. P., and Werner, J. H., A review of quantum imaging methods and enabling technologies, *Materials Today Quantum*, vol. 6, 2025, art. no. 100044, ISSN 2950-2578, available at <https://doi.org/10.1016/j.mtquan.2025.100044>.
4. Megginson, R., and Huston, T., Putting the Blue back in Red, White and Blue – Decarbonisation of the United States maritime industry with advanced nuclear, CORE POWER (UK) Ltd., 2022.
5. “Living up to the Hype of Hyperspectral Aquatic Remote Sensing: Science, Resources and Outlook”, Heidi M. Dierssen, Steven G. Ackleson, Karen E. Joyce, Erin L. Hestir, Alexandre Castagna, Samantha Lavender, and Margaret A. McManus. *Frontiers in Environmental Science*, Vol. 9, Article 649528, June 2021.
7. Glodo, J., et al., “Integrated Neutron Detector for Handheld Systems.” *IEEE Transactions on Nuclear Science* 60, no. 2 (2013): 903–7. <https://doi.org/10.1109/TNS.2013.2252020>.
8. Menge, Peter R., et al., “Design and Performance of a Compact Cs2LiLaBr6(Ce) Neutron/Gamma Detector Using Silicon Photomultipliers.” 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), October 2015, 1–5. <https://doi.org/10.1109/NSSMIC.2015.7581858>.
15. Monson LA, et al., “Dose-response effect of human equivalent radiation in the mandible”, *J. Craniofac Surg.* 2013;24:1593-1598. <https://doi.org/10.1097/SCS.0b013e31826cfeea>.
6. Ferrera, M., Arnaubec, A., Istenič, K., Gracias, N., and Bajjouk, T., Hyperspectral 3D Mapping of Underwater Environments, in *Proceedings of the 2021 IEEE/CVF International Conference on Computer Vision Workshops (ICCVW)*, October 2021.
8. D. B. Gillis, *Detection of Underwater Objects in Hyperspectral Imagery*, 2016 8th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing

- (WHISPERS), Los Angeles, CA, 2016, pp. 1–5,
<https://doi.org/10.1109/WHISPERS.2016.8071732>.
9. J. Glodo et al., *Integrated Neutron Detector for Handheld Systems*, IEEE Transactions on Nuclear Science, vol. 60, no. 2, pp. 903–907, 2013,
<https://doi.org/10.1109/TNS.2013.2252020>.
 9. P. R. Menge et al., *Design and Performance of a Compact Cs₂LiLaBr₆(Ce) Neutron/Gamma Detector Using Silicon Photomultipliers*, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), October 2015, pp. 1–5,
<https://doi.org/10.1109/NSSMIC.2015.7581858>.
 10. G. Pausch et al., *Thermal Neutron Detection in Mixed Neutron-Gamma Fields With Common NaI(Tl) Detectors*, IEEE Transactions on Nuclear Science, vol. 69, no. 8, 1893–1904 (2022), available at <https://doi.org/10.1109/TNS.2022.3184452>.
 11. D. F. Bennett et al., *Low Power, Dual Mode Detectors for Nuclear Security Applications*, 2024 IEEE Nuclear Science Symposium (NSS), Medical Imaging Conference (MIC) and Room Temperature Semiconductor Detector Conference (RTSD), October 26, 2024, 1–1, available at <https://doi.org/10.1109/NSS/MIC/RTSD57108.2024.10656500>.
 12. R. J. Cooper et al., *Networked Sensing for Radiation Detection, Localization, and Tracking*, J. Phys.: Conf. Ser., vol. 2586, 012125 (2023).
 13. M. S. Bandstra et al., *Background and Anomaly Learning Methods for Static Gamma-Ray Detectors*, IEEE Transactions on Nuclear Science, vol. 70, no. 10, 2352–2363 (Oct. 2023), available at <https://doi.org/10.1109/TNS.2023.3313996>.
 14. D. Hellfeld et al., *Gamma-Ray Point-Source Localization and Sparse Image Reconstruction Using Poisson Likelihood*, IEEE Transactions on Nuclear Science, vol. 66, no. 9, 2088–2099 (Sept. 2019), available at <https://doi.org/10.1109/TNS.2019.2930294>.
 16. Mark A. Hill et al., *The importance of standardization and challenges of dosimetry in conventional preclinical radiation biology research*, Br. J. Radiol., vol. 98, no. 1171, 993–1004 (July 2025), available at <https://doi.org/10.1093/bjr/tqaf066>.
 16. L. A. Monson et al., **Dose-response effect of human equivalent radiation in the mandible**, J. Craniofac. Surg., vol. 24, 1593–1598 (2013), available at <https://doi.org/10.1097/SCS.0b013e31826cfeea>.
 17. Ghandhi SA, et al., *Discordant gene responses to radiation in humans and mice and the role of hematopoietically humanized mice in the search for radiation biomarkers*.
 18. Soultanidis G, et al., “Development of an anatomically correct mouse phantom for dosimetry measurement in small animal radiotherapy research”, Phys Med Biol. 2019;64(12):12NT02. <https://doi.org/10.1088/1361-6560/ab215b>.
 19. Schyns LE, et al., *Murine vs human tissue compositions: implications of using human tissue compositions for photon energy absorption in mice*, Br. J. Radiol. 92(1095):20180454 (2018), <https://doi.org/10.1259/bjr.20180454>.
 19. Soultanidis G, et al., *Development of an anatomically correct mouse phantom for dosimetry measurement in small animal radiotherapy research*, Phys. Med. Biol. 64(12):12NT02 (2019), <https://doi.org/10.1088/1361-6560/ab215b>.
 20. Price G, et al., *An open source heterogeneous 3D printed mouse phantom utilizing a novel bone representative thermoplastic*, Phys. Med. Biol. 65(10):10NT02 (2020), <https://doi.org/10.1088/1361-6560/ab8078>.
 21. Department of Defense, *JROCM 010-15 Radiological Detection System (RDS) Capability Development Document (CDD)*, January 13, 2015.

22. National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Nuclear and Radiation Studies Board; Committee on Radioactive Sources: Applications and Alternative Technologies, *Radioactive Sources: Applications and Alternative Technologies* (Washington, DC: National Academies Press (US), June 14, 2021), PMID: 34524768.

Topic 25: Nuclear Detonation Detection

The Office of Nuclear Detonation Detection within the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development office, develops novel technologies within two broad topics; underground nuclear explosion monitoring technologies that improve the precise timing and integration of multiple sensing modalities and support large-scale experimental campaigns that collect synchronized data from multiple locations; new technologies for radiation resistant microcircuits that improve current technology and develop materials and tools for radiation resistant applications. Applications are of interest in the following areas.

Areas of Interest

a. Integrated Data Acquisition System for Large-Scale Field Experiments: Data acquisition systems are a key component for any experiment [1,2]. They are the interface between researchers and the instrumentation deployed to record the experiment. In the case of large experiments, several distributed sensors may be operated independently, but the research team will want to ensure that they are all in good condition and record with accurate timing. This requires an integrated data acquisition system to coordinate the individual data acquisition systems for each sensor [3]. This coordination includes precise time synchronization, remote command and control, and data extraction and backup for a range of sensors, often deployed in challenging environments such as an underground tunnel complex.

The Office of Nuclear Detonation Detection is soliciting research in integrated data acquisition systems useful in underground nuclear explosion monitoring applications, in which dynamic seismoacoustic and electromagnetic energy is propagated. Of interest are systems that would lead to fieldable nodes in rugged environments with practical size, weight, and power requirements and data transmission rates. Example system characteristics may include but are not limited to modular design with rapid communication between nodes, large data storage capacity with fast I/O, timing synchronization through cabled GNSS antenna, ability to interface with variety of deployed data acquisition systems, system-wide state of health tracking, and external communication for remote command and control.

b. Fieldable Calibration Tool for Nuclear Explosion Monitoring: The Office of Nuclear Detonation Detection is soliciting research in in-field sensor calibration approaches useful in underground nuclear explosion monitoring applications in which dynamic seismoacoustic and electromagnetic energy is propagated. Of interest are methods that would lead to quantified mapping from deployed sensors to metrological quantities with practical size, weight, and power for use in outdoor environments.

The sensors of interest include seismometers, infrasound sensors (Nief et al., 2018), hydroacoustic sensors, and electromagnetic field sensors [4,5]. The primary standard calibration for these sensors is in a test laboratory during which as many factors as possible can be tightly controlled [6-9]. However, these calibrations cannot capture the full suite of factors that

influence the instrument response when a sensor is fully deployed. This has motivated methods of calibration in the field, but running in-field calibrations is an uncommon procedure [10,11]. Example device characteristics may include, but are not limited to, the ability to interface with sensor and datalogger calibration pulse in volts, an amplitude calibration sensitivity (e.g. V/m/s, V/Pa, etc...) to within +/-5% precision, and operational temperature range from 0 to 40 °C.

c. Detonation Detection Systems: In addition to the specific subtopics listed above, applications in other areas relevant to this topic are invited. These include seismometer improvements (e.g., reduced size, improved sensitivity, reduced power requirements), seismic array improvements, infrasound sensor improvements, hydroacoustic sensor improvements, or other ways to detect acoustic energy underground, on the surface, or in the atmosphere at regional to global distances (>200km) [12-14]. Improvements should substantially enhance capabilities when compared to existing sensors or techniques.

d. Radiation Resistant Plastic Encapsulated Microcircuits with Undiminished Performance, High-Yield, and Lower Cost: Long duration space-based missions would greatly benefit from the availability of inexpensive and rapidly developed radiation resistant microcircuits. Plastic Encapsulated Microcircuits (PEM) are of keen interest in this regard for the new generation of proliferated spacecraft constellations being generated by commercial entities and the military. Of particular interest is the potential for PEMs to augment space qualified parts which are rare, expensive, have extraordinary lead times and quickly become obsolete with time. Most government agencies and commercial entities involved in spacecraft development understand that the need for faster, cheaper, and more abundant electronic parts is never going to diminish. Related questions are:

- Can PEMs meet the reliability requirements of space-based missions?
- Can they be screened?
- Do post-delivery tests and evaluations provide sufficient knowledge of the parts to satisfy mission requirements?
- Can PEMs be expected to last 15 years in space environments?
- What, if anything, can be done post-manufacturing to gain additional confidence in the suitability of PEMs parts for long term use in space?

PEMs capable of high radiation resistance, undiminished performance, rapid development, and low-cost are the ultimate objectives of this research. The Office of Nuclear Detonation Detection is soliciting research to develop radiation resistant microcircuit plastic encapsulation methods capable of meeting the following specifications:

- Radiation survivability: up to 100krad total ionizing dose
- Minimizing Bremsstrahlung Effects
- Undiminished performance due to incident radiation
- Functional production yields > 80%
- Materials cost: 5-10 times lower than standard space qualified parts

A Phase I research effort could identify the candidate materials and their potentials and demonstrate pathways for meeting radiation resistance and cost performance goals.

References

1. Springer, Fundamentals to Applied Design: Data Acquisition Systems, M. D. Di Paolo, 2013, New York, NY, USA, available at <https://link.springer.com/book/10.1007/978-1-4614-4214-1>.

2. Park, J., and Mackay, S., 2003, *Practical data acquisition for instrumentation and control systems*. Newnes.
<https://books.google.com/books?hl=en&lr=&id=vzrkldir0ukC&oi=fnd&pg=PR17&dq=Practical+data+acquisition+for+instrumentation+and+control+systems.&ots=jsBViOYhZV&sig=exKnzIQqybBM2CITXWjU3oJWOo8#v=onepage&q=Practical%20data%20acquisition%20for%20instrumentation%20and%20control%20systems.&f=false>
3. Strickland, Christopher E., et al., Low Yield Nuclear Monitoring Physics Experiment 1 – Integrated Data Acquisition System Design and Initial Observations, Oct. 2024, available at <https://doi.org/10.2172/2564221>.
4. Wielandt, E., Seismic Sensors and Their Calibration, version August 2011, 2011, DOI: 10.2312/GFZ.NMSOP-2_ch5, available at https://gfzpublic.gfz.de/rest/items/item_56076/component/file_61055/content.
5. Nief, G., et al., 2018, New Generations of Infrasound Sensors: Technological Developments and Calibration. In Le Pichon, A., Blanc, E., Hauchecorne, A. (eds) *Infrasound Monitoring for Atmospheric Studies*, Springer, Cham. DOI: 10.1007/978-3-319-75140-5_2 https://doi.org/10.1007/978-3-319-75140-5_2
6. Larssonier, F., et al., Comparison on Seismometer Sensitivity Following ISO 16063-11 Standard, 19th International Congress of Metrology, 27033, 2019, DOI: 10.1051/metrology/201927003, available at <https://doi.org/10.1051/metrology/201927003>.
7. Schiavi, A., et al., Dynamic Calibration System for Seismometers: Traceability from 0.03 Hz up to 30 Hz, *Measurement: Sensors*, 18, 2021, DOI: 10.1016/j.measen.2021.100255, available at <https://doi.org/10.1016/j.measen.2021.100255>.
8. Rodrigues, D., et al., A Laser Pistonphone Designed for Absolute Calibration of Infrasound Sensors from 10 mHz up to 20 Hz, *Metrologia*, 60(1), 2022, DOI: 10.1088/1681-7575/aca0fa, available at <https://iopscience.iop.org/article/10.1088/1681-7575/aca0fa/meta>.
9. Rust, M., et al., Primary Calibration for Airborne Infrasound Utilizing the Vertical Gradient of the Ambient Pressure, *Metrologia*, 60(4), 2023, DOI: 10.1088/1681-7575/acd941, available at <https://iopscience.iop.org/article/10.1088/1681-7575/acd941/meta>.
10. Pavlis, G. L. and Vernon, F. L., 1994, Calibration of seismometers using ground noise, *Bulletin of the Seismological Society of America*, 84 (4), 1243-1255, DOI: 10.1785/BSSA0840041243
<https://pubs.geoscienceworld.org/ssa/bssa/article/84/4/1243/119878/Calibration-of-seismometers-using-ground-noise>
11. Kristoffersen, S. K., et al., On-site Infrasound Calibration to Correct Wave Parameter Estimation, *The Journal of the Acoustical Society of America*, 155, 1780–1798, 2024, DOI: 10.1121/10.0025131, available at <https://doi.org/10.1121/10.0025131>.
12. Dannemann Dugick, F. K., et al., 2023, Introduction to the Special Section on Seismoacoustics and Seismoacoustic Data Fusion, *Bull. Seismol. Soc. Am.* 113, 1383-1389, DOI: 10.1785/0120230049 <https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/113/4/1383/624450/Introduction-to-the-Special-Section-on?redirectedFrom=fulltext> (October 23, 2023)
13. Maceira, M., et al., 2017, Trends in Nuclear Explosion Monitoring Research & Development – A Physics Perspective, Technical Report No. LA-UR-17-21274. Los Alamos National Lab.(LANL), Los Alamos, NM United States, DOI: 10.2172/1355758 <https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-17-21274> (October 23, 2023)
14. Kalinowski, M.B., et al., 2021, Introduction to the Topical issue of nuclear explosion monitoring and verification: scientific and technological advances, *Pure and Applied*

Topic 25 General References

1. *Polymeric Composite Materials for Radiation Shielding*, National Center for Biotechnology Information, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7857349/>.
2. U.S. Department of Energy, Technical Report, <https://www.osti.gov/servlets/purl/1671997>.¹
3. Requirements for Plastic Encapsulated Microcircuits in Space Applications, SAE International, AS6291/1; AS6294/1.²
4. *Requirements for Plastic Encapsulated Discrete Semiconductors in Space Applications*, SAE International, AS6291/3, <https://www.sae.org/standards/content/as6294/3/>.³
5. *General Specification for Integrated Circuits (Microcircuits) Manufacturing*, U.S. Department of Defense, MIL-PRF-38535 Rev. K, http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-38535K_48842/.
6. *2013 NEPP ETW Briefing on Introduction of Class Y*, NASA Electronic Parts and Packaging Program, https://nepp.nasa.gov/workshops/etw2013/talks/Tue_June11_2013/1300_Agarwal_Class%20Y%20Status%20Overview.pdf.

¹ An overview of basic radiation effects on polymers.

² PEM Standards: requirements for Plastic Encapsulated Microcircuits in Space Applications. This document establishes common industry practices and recommended screening, qualification, and lot acceptance testing of Plastic Encapsulated Microcircuits (PEMs) for use in space application environments.

³ Requirements for Plastic Encapsulated Discrete Semiconductors in Space Applications. This document establishes the requirements for screening, qualification, and lot acceptance testing of Plastic Encapsulated Discrete Semiconductors (PEDS) for use in space application environments. The scope of this document is intended for standard silicon based technology only, but the process and methodology described within can be adopted for other technologies such as Silicon Carbide, Gallium Nitride, and Gallium Arsenide. However, when non-silicon based technology parts are being used, the device characterization shall be modified, and it is recommended to use available industry standards based upon published research/testing reports for those technology to address applicable physics of failure.