APPENDIX FOR FY 2023 TYPE A LDRD CALL

DESCRIPTION OF TOPICAL AREAS AND POINTS OF CONTACT

Accelerator Science & Technology

The call for Accelerator Science and Technology LDRD proposals is focused on new or enhanced programs co-aligned with major Laboratory initiatives. This thrust in the LDRD call focuses on projects that leverage the Laboratory's deep accelerator expertise and unique suite of accelerator capabilities to support identified national and Laboratory needs. Efforts that utilize multiple accelerator capabilities at the Lab as well as those that involve extensions or adaptation of core Laboratory technology to address these needs are of particular interest.

Proposals that are responsive to recent community planning efforts, Basic Research Needs reports, and reports from the National Academies of Science that rely on accelerator-related capabilities and technologies are also encouraged. Examples of these reports include:

- A Community Plan for Fusion Energy and Discovery Plasma Sciences
- Basic Research Needs Workshop on Compact Accelerators for Security and Medicine
- Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light (2018).

POC: Mark Palmer, mpalmer@bnl.gov.

Atmospheric and Climate Science

Climate solutions for building a clean energy future, addressing human health and environmental equity, and ensuring national security, require better knowledge of current and future states of the atmosphere than is currently available. Atmospheric and Climate Science LDRD proposals should focus on novel sensing and simulation approaches that will contribute to improved predictability and predictions of the atmospheric and climate systems. Methodologies may cover a range of measurement and modeling scales that serve a range of applications – from the fine-scale urban environment for energy efficiency applications to regional scales that contribute to improved basic understanding of climate processes. Novel strategies and state-of-the-art technologies such as 5G principles, methods that provide for ultrahigh-resolution or dynamic measurements, 4-dimensional characterization of the atmosphere, and data-driven simulation methods are encouraged. POC: Allison McComiskey, amccomiskey@bnl.gov.

Clean Energy

Clean energy is a national imperative encompassing an array of research areas. These include energy storage, integration of renewable energy generation, energy efficiency, closing the carbon cycle by chemical or biological conversion, and "green" hydrogen generation and use. The LDRD proposals should explain the relationship to clean energy and the impact on BNL's program strategy as well as energy technology options if successful. POC: etakeuchi@bnl.gov.

Discovery Science Driven by Human-AI-Facility Integration

As a Lab at the forefront of experimental facilities design and Artificial Intelligence (AI) research, BNL has developed the concept of discovery science driven by the deep integration of humans, AI, and facilities. The idea is that this integration allows the whole to "think scientifically," incorporating scientific goals into the operation of the facilities and enabling new discoveries. The BNL vision for human-AI-facility integration is to automate routine processes and to create layers of nested, intelligent systems that can strategize together with their users and operators about the best experimental design, execution, and analysis.

Such a radical shift in facilities design and operation will necessitate changes at all levels – accelerators, choice of technique, detectors, sensors, controls, data acquisition, and analysis – and an integrated infrastructure to support this vision. BNL LDRD investment will therefore focus both on pushing the boundaries of the state-of-the-art in various domains and on overcoming operational deployment challenges in highly constrained environments. Initial research topics are: 1) AI enhanced detectors, accelerators, and sensors; 2) optimal experimental design and steering; and 3) migration to operation.

1) AI enhanced Detectors, Accelerators and Sensors

Against the backdrop of exponentially increasing data rates, this technical area requires more powerful, lower-level processing capabilities to produce the best possible value of information within stringent constraints of power, reliability, and accuracy, and operation in harsh conditions. The scientific workflows that the detectors, accelerators (including computational accelerators) and sensors contribute to are complex hardware-software architectures including computational elements of varied characteristics (e.g., GPU and TPU, neuromorphic, optical), memory and storage throughout the pipeline from the detector to the analysis stages, advanced algorithms (including AI), networks, and specialized software for control and optimization. Best tools and practices of co-design, management, and optimization need to be developed and applied to maximize the scientific output from these experiments. Required is rational co-design, including dynamic optimization throughout the workflow from data collection to analysis and the requisite feedback loops.

2) Optimal experimental design and steering

In the context of human-AI-facility integration, a foundation of AI and Applied Math methods is needed to analyze large, streaming data sets, integrate information, offer actionable information to users, operators, and systems to optimize experiments and indeed the choice of experiments to be performed. Specific areas of emphasis include continued development of algorithms for end-to-end automation, uncertainty propagation, and optimal design under uncertainty for multi-stage, multi-fidelity, multi-modal workflows, computer simulations (digital twins) for accelerators, detectors, sensors, controls, experiments, computational hardware, and data acquisition and analysis, to support the design and execution of experiments, guide the operation optimization of facilities, and study their behavior.

3) Migration to Operation

Success in this area will depend on an integrated infrastructure fabric that provides seamless and transparent access to AI and HPC compute, storage, and network capabilities. The user should neither need to know nor care where these resources are located, and the user experience should not change if the user is on site or remote. To this end, there is a critical need for research in: 1) scalable and scientific workflows with explicit quality of service and performance bounds; and 2) dynamic end-to-end co-allocation and provisioning of compute, network, and data resources. POC: Frank Alexander, falexander@bnl.gov.

High Energy Physics: Understanding the Origin of Space and Time

BNL is a leader of global particle physics experiments to explore the fundamental constituents of nature with ultimate precision and to discover phenomena that signal physics beyond the Standard Model. BNL serves as the U.S. host institution for the energy frontier ATLAS experiment; provides quadrupole magnets for the High Luminosity Large Hadron Collider; leads the utilization of intense neutrino fluxes provided by Fermilab's short baseline neutrino beam; leads U.S. participation in the Belle II experiment, which provides a unique sample of heavy quark decays; and contributes to the dark energy and early Universe studies by the Rubin Observatory and the Lunar Surface Electromagnetics Experiment Night mission.

Looking further ahead, BNL researchers are developing the foundation for new scientific opportunities, including those at future energy frontier colliders; next-generation neutrino experiments, in particular, the Deep Underground Neutrino Experiment; and advanced computing, software, and detector and accelerator technologies for next-generation colliders; and neutrino, dark matter, and dark energy experiments. Across these thrusts, BNL's high energy theory program will interpret the experimental results and help guide the experimental program of the future.

The U.S. particle physics long term future planning process, aka Snowmass, to be followed by the Particle Physics Projects Prioritization Panel (P5), provides exciting opportunities for BNL to lead in new areas of science and technology. With the Snowmass process converging later this year, the main directions for the future are starting to take shape and will require Lab investments to develop them for the P5 process and beyond. Proposals to develop and strengthen options for future high energy physics facilities, experiments, theoretical ideas, and technologies are strongly encouraged. POC: Hong Ma, hma@bnl.gov.

Isotope Production and R&D Capabilities

The DOE has played a major role in the development of radionuclides and of the technology necessary to produce them in useful quantities and purity. These developments were made by multidisciplinary teams consisting of experts in physics, biology, engineering, chemistry, and math. Today radionuclides have many applications in areas such as biology, medicine, pharmaceuticals, the physical sciences, engineering, and national security. Isotopes provide cost effective means to perform non-invasive evaluations, to treat patients, to power batteries in remote areas, sources for industry applications, and for national security. Radionuclides are strategic commodities essential to the nation's economic, scientific and technical strengths and resilience. The mission of the Isotope Program is to produce and/or distribute radioactive and stable isotopes that are in short supply, ensure robust domestic supply chains, and reduce U.S. dependency on foreign supply to ensure national preparedness. Currently there exists a gap in cyclotron produced isotopes that have been traditionally supplied by foreign suppliers. The isotopes of critical need, currently and in the future, require medium to high energy particle beams, new methods for making targets, and precise, high-quality nuclear data related to their production cross sections and decay properties. Novel generator systems will also need to be explored to increase remote access to critical isotopes. This LDRD call focuses on optimizing advanced novel components in sources and accelerators, innovative generator systems, and precise nuclear data that are needed to support the Lab's strategic vison in realizing transformative production and R&D capabilities in the DOE Isotope Program. Proposals should demonstrate how they can address the production gaps and mitigate reliance on foreign supply chains. POC: ccutler@bnl.gov.

Quantum Information Science and Technology

BNL's Quantum Information Science and Technology (QIST) program has several strong elements: the Co-design Center for Quantum Advantage (C^2QA); the quantum network lab and testbed; the QPress; and interdisciplinary teams that focus on materials, technologies and techniques, algorithms and computation, partnership, and workforce development. Following multiple efforts focused on improving or developing new types of quantum devices for applications in quantum sensing, communication, and computing and adopting QIST approaches to develop new methodologies, the emphasis of this year's LDRD call is on expanding co-design efforts. Research areas include: demonstration of hybrid technologies enabling large and distributed systems; combination of classical and quantum approaches; characterization techniques, theoretical models, and new algorithms to improve quality and usability of non-perfect quantum systems. POC: Gabriella Carini, carini@bnl.gov.

Research and Development towards the Second Detector at the Electron-Ion Collider

BNL will continue to be the leading laboratory in the world for nuclear physics research in the coming decades with the construction of the Electron-Ion Collider (EIC). The EIC will be the tool for resolving fundamental science questions about how the structures of the nucleons and atomic nuclei emerge from the dynamics of quarks and gluons, how gluons generate nearly all the mass of visible matter in the universe, and whether a new state of matter forms when gluons are highly packed inside nuclei. The EIC project, which is funded by the Office of Nuclear Physics in the Department of Energy's (DOE) Office of Science, includes significant funding for a single project detector. The recommendation of the EIC project detector was made in March 2022 by the EIC Detector Proposal Advisory Panel (DPAP) https://www.bnl.gov/dpapanelmeeting/ after a long and careful process to review three outstanding proposals (ATHENA, CORE, and ECCE). Members of the international EIC scientific community have presented a compelling case that a second detector, which is not in the scope of the EIC project, is needed to take full advantage of the unique capabilities of the EIC. The DPAP also supports the idea of a second EIC detector enthusiastically. The LDRD proposal(s) should focus on R&D activities towards the second EIC detector that are complementary in technologies and/or science to the EIC project detector. POC: Jamie Dunlop: dunlop@bnl.gov.