FY25 LDRD Calls & Research Needs

Thank you for your interest in the Sandia National Laboratories' LDRD program! Each program area below contains a description of the program, along with high-level research needs and keywords. Please use the form on our webpage to submit your research summaries that align with the program areas below. You may select more than one area per submission. Additionally, select keywords to assist Sandia researchers to review your summary.

Contact AcademicPrograms@sandia.gov with any questions.

Acronym List:

DOE	Department of Energy
FY	Fiscal Year
IA	Investment Area
LDRD	Laboratory Directed Research & Development

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Introduction

Sandia's LDRD program is organized around seven foundational research areas, five major portfolios, and strategic initiatives.

- **Research Foundations** steward discipline-based ST&E competencies that address the extensive national security challenges within Sandia's mission space. Each of the Research Foundations focuses on stewarding differentiating or unique capabilities in seven areas.
- Sandia oversees five major portfolios that address national security mission challenges. LDRD **Mission Foundations** align with the portfolios and conduct the applied research needed to develop capabilities and demonstrate solutions.
- **Strategic Initiatives** (SI) promote strategic collaborations and Chief Research Office (CRO)/Labs-directed initiatives. They are not included in this document.

Research Foundations

Biosciences (BIO)

Overview

The Bioscience Research Foundation (Bio RF) advances foundational bioscience and biotechnology to position Sandia at the frontiers of science and national security.

For more information, a description of the Bioscience Research Area at Sandia can be found on this webpage.

Keywords

- Biothreats
- Biomanufacturing
- Biosurveillance
- Biosecurity
- Biocontainment

Key Research Foci for the FY25 LDRD Call

Focus is on answering one of the following questions:

1. How can one accelerate identification of unknown biothreats, novel organisms, or pathways for sustainable biomanufacturing?
2. How can one predict an organism's phenotype from its genotype and other systems-level data, or predict the genotypes that yield a desired phenotype?
3. How can one design biological systems for a more flexible, scalable, and resilient bioeconomy?

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Computing & Information Sciences (CIS)

Overview

The Computing and Information Sciences Research Foundation (CISRF) drives innovative research in mathematics, computer science, computational sciences, and data sciences to position Sandia at the frontiers of national security challenges.

For more information, a description of the Computing, Information Science and Mathematics Research Area at Sandia can be found on this webpage.

Keywords

- Computational Science
- Computing Systems
- Information Science
- Trusted AI
- Generative AI
- Human Trust

Key Research Foci for the FY25 LDRD Call

- **Computational Sciences** such as 1) Robust/scalable and accurate computational formulations and solution methods for complex multiphysics forward problems including multimaterial/multifluid algorithms; and 2) Methods for rigorous multiphysics coupling, and/or integration of multiple physics across engineering domains, possibly involving hierarchical, heterogeneous, and/or multifidelity models;
- **Computing Systems** such as theoretical foundations of emerging computing paradigms; specialization and delivery of CaaS workflows on cloud and advancing cloud methodologies to enable high-fidelity simulation; autonomous computing systems and workflow management; theoretical advances in quantum algorithms, quantum control and circuit design, and quantum architecture; developments towards a robust theoretical framework for programming and analyzing neuromorphic algorithms and systems.
- **Information Sciences** such as methods to explain, visualize, interpret, and communicate analytic results; data fusion from diverse sources; exploiting new data sources; processing and downsizing sensor data at the source; anomaly detection; methods for generating synthetic data; mission-focused data analytics including unsupervised learning and streaming analytics; managing dynamic data; formal methods; and algorithms & metrics to assess and monitor human/machine teaming.
- **Trusted AI** such as method for certifying AI software consistent with nascent definitions being developed by NIST and the DOE AITO office.
- **Trusted Generative AI for Mission Applications** such as 1) Assessment of applicability, reliability, limits of capability, and security of GenAI; 2) Assessment of development cost versus impact on user tasks/decision making on mission problems; and 3) Algorithmic specialization for training and inference efficiency relative to mission domain/task or specialized hardware.
- **Human Trust** such as cognitive aspects of trust, processes to enhance trust, dynamics of trust in computational environments, and systems with emergent behavior. Research is also invited on human-understandable computational results, considering uncertainty, credibility, transparency, explainability, and provenance tracking impacts within the interplay of system objectives and human trust.
- **National Security Information Sciences & Technology (NSIST)**
  - NSIST **accelerates** the development & application of **Sandia-differentiated information science capabilities** to specific national security mission applications. We invest in capabilities with a **3-5 year time horizon to mission impact**. NSIST complements CIS IA in both focus area and time horizon to mission impact.
  - Four technical thrusts, focusing on Information Science technology gaps identified by survey of Mission Foundations/Campaigns:
    - Human-Machine Teaming to Enable Decision Making
    - Information Science Capabilities for ND Mission Concerns
    - Novel Approaches for Understanding and Mitigating National and Global Risks
    - Mission Data-Science Challenges

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Earth Sciences (EARTH)

Overview

The Earth Sciences Research Foundation addresses the coupled thermal, chemical, biological, hydrological, physical, energy propagation, and mechanical behavior of naturally occurring, significantly heterogeneous, and dynamic materials, ensuring integrated understanding and information across scales ranging from nanometers to hundreds of kilometers. Quantitative elements include detailed characterization, data analytics, and machine learning applied to both interpretation and simulation, new numerical techniques, and all forms of modeling.

For more information, a description of the Earth, Energy and Environmental Science Research Area at Sandia can be found on this webpage.

Keywords

- Subsurface sensing
- Climate intervention
- Greenhouse gas monitoring
- Climate impact analysis
- Extreme weather prediction

Key Research Foci for the FY25 LDRD Call

- Sensing technologies for subsurface systems (enabling carbon capture, utilization, and storage (CCUS), hydrogen storage, and/or geothermal energy optimization)
- Understanding of climate intervention approaches and risks
- Greenhouse gas monitoring
- Climate impact analysis, including extreme weather analysis
- Understanding of fundamental earth system processes—through sensing, analysis, and modeling—that limit the fidelity of climate models such as E3SM, such as the release of methane from thawing permafrost

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Engineering Sciences (ES)

Overview

The goal of the Engineering Sciences Research Foundation is to position Engineering Sciences for complex and unpredictable future challenges. The foci are, with increasing agility, to advance scientific understanding of physical phenomena, to drive innovation of computational modeling and simulation tools, and to accelerate development of high-fidelity, spatially and temporally resolved experimental diagnostics.

For more information, a description of the Engineering Sciences Research Area at Sandia can be found on this webpage.

Keywords

- Digital Engineering
- Coupled/Multi Physics
- Scientific Discovery
- Experimental test/ diagnostics
- Design
- Qualification
- Validation & Verification
- Uncertainty Quantification
- ML/AI

Key Research Foci for the FY25 LDRD Call

- Fundamental and coupled physics – discovery and modeling
- Next Generation Simulation – novel computational methods to reduce time to solution, accelerate workflow, etc.
- Diagnostics and testing – high-fidelity, spatially and temporarily resolved experimental diagnostics
- Data Interrogation and Integration – data-centric approaches to engineering science problems

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Materials Sciences (MS)

Overview

The Materials Science Research Foundation (MSRF) Investment Area (IA) advances, sustains, supports, and nurtures the materials science capabilities that Sandia needs to:

- Enable science-based materials solutions for enduring and emerging missions and national needs;
- Support the materials discovery, synthesis, characterization, and processing competencies underpinning current and future materials applications;
- Help maintain Sandia's leadership in the international scientific community; and;
- Enable new missions, research directions, and/or scientific opportunities for Sandia.

For more information, a description of the Materials and Advanced Manufacturing Research Area at Sandia can be found on this webpage.

Keywords

- Advanced Manufacturing
- Materials Discovery
- Materials Sustainability
- Extreme Environments

Key Research Foci for the FY25 LDRD Call

1. Accelerating the Discovery, Delivery, and Application of Materials Solutions
2. Advanced Manufacturing for Agility and Innovation
3. Materials Advancing Reliability and Sustainability for Life Cycle Management
4. Materials Properties and Performance in Extreme Environments

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Nanodevices & Microsystems (NM)

Overview

The Nanodevices and Microsystems Research Foundation seeks to discover and control new phenomena at the nanoscale and microscale; and create or prove new concepts, devices, components, subsystems, and systems.

For more information, a description of the Nanodevices and Microsystems Research Area at Sandia can be found on this webpage.

Keywords

- Nanodevices
- Microsystems
- Semiconductors
- Microelectronics
- Quantum

Key Research Foci for the FY25 LDRD Call

- **Trusted Resilient Microsystems:** The development of concepts, devices and tools that enable the understanding and creation of extreme-environment-hardened microelectronics and microsystems that are resistant to subversion. This includes proposals that seek to understand the impact of combined extreme environments on microsystem performance (ionizing radiation with high temperature, high power electromagnetic radiation, high shock, etc.).
- **Advanced Computing Technologies:** The development of nanoscale and microscale concepts, devices, tools, and systems that extend performance improvements beyond Moore's Law, including quantum computing concepts.
- **Optoelectronics of the Future:** The discovery and creation of advanced optoelectronics, at the nanoscale and microscale, which provide new functionality.
- **Advanced Microsystem Sensor Technologies:** The development of nanoscale and microscale concepts, devices and systems that enable physical, chemical, radiation, nuclear materials, and explosives detection that exceed current limitations in selectivity, sensitivity, and/or robustness.
- **Nanoscale- and Microscale-enabled Performance:** The discovery and exploitation of new functionality that results from phenomena unique to the nanoscale and microscale. This thrust seeks to invest in enabling phenomena resulting from scale-dependent effects such as non-continuum and quantum phenomena.

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Radiation, Electrical, & High Energy Density Sciences (REHEDS)

Overview

The REHEDS Research Foundation seeks to advance science, technology, and engineering in the four disciplines outlined on the left below. These disciplines play a pivotal role in supporting a safe, secure, and reliable stockpile that is viable today and will be robust to evolving threats and technological surprise.

For more information, a description of the Radiation Effects and High Energy Physics Research Area at Sandia can be found on this webpage.

Keywords

- Radiation Effects
- Electrical Sciences
- High Energy Density
- Dynamic Materials Properties
- Inertial Confinement Fusion

Key Research Foci for the FY25 LDRD Call

- **Radiation Effects Science (RES):**
  - Effects caused by single and combined radiation environments
  - Impacts on materials, devices, components, and systems which can cause complex physical, chemical responses
- **Electrical & Electromagnetic Science (EES):**
  - Effects of electromagnetic radiation
  - Particular focus on electrical
- **High Energy Density Science (HEDS):**
  - Experimental, theoretical, computational study of material properties, radiation transport, inertial confinement fusion, and other processes at extreme temperatures, densities, and pressures
  - High energy density plasmas are efficient, powerful sources of fusion neutrons and x rays in the 0.1-100 keV range, applicable to RES studies
- **Pulsed Power Science and Technologies (PPS&T):**
  - Physical principles that underlie efficient creation and application of electrical energy through pulsed power technologies
    - Enabling for the three disciplines above

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Advanced Science & Technology (AS&T)

Overview

Sandia's Advanced Science & Technology (AS&T) Mission Foundation supports our DOE Office of Science (SC) program, using unique, scientific, and cross-cutting capabilities – e.g., facilities, people, and experimental and computational platforms – to support SC's scientific priorities and DOE's missions.

For more information, a description of the Physical Sciences Research Area at Sandia and the DOE Office of Science program can be found on this webpage.

Keywords

- Climate
- Discovery
- Computation
- Interfaces
- Materials

Key Research Foci for the FY25 LDRD Call

Four strategic goals, focused on accelerating discovery science using high performance computing, reducing uncertainty in earth and environmental system predictability, discovery science of carbon negative processes, and elucidating chemistry and transport at interfaces, guide our investment. This investment supports the priorities of Sandia SC Programs in:

1. Advanced Scientific Computing Research (ASCR)
2. Basic Energy Sciences (BES)
   - Materials Sciences and Engineering
   - Chemscience & Geoscience
   - Center for Integrated Nanotechnologies (CINT)
3. Biological and Environmental Research (BER)
   - Biological Systems Science
   - Earth & Environmental Systems Science
4. Fusion Energy Sciences (FES)

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Energy & Homeland Security (E/HS)

Overview

The Energy & Homeland Security (E/HS) portfolio secures the nation's critical infrastructures and environment against attacks, threats, and climate change by performing world-class R&D. Research needs aligned with E/HS high-priority strategic needs are described in the six Priority Areas listed below.

For more information, a description of the Energy Program at Sandia can be found on this webpage. A description of the Homeland Security Program Area at Sandia can be found on this webpage.

Keywords

- Energy Supply Chain
- Reduce Carbon Intensity
- Greenhouse Gas Emissions
- Data to Decisions
- Physical Security
- Threat-informed Cybersecurity

Key Research Foci for the FY25 LDRD Call

E/HS is focused on achieving goals in our Energy strategy and strengthening Homeland Security differentiating capabilities.

The Energy Goals in three strategic priority areas:

1. Methods to assess energy technology impacts on the environment,
2. Technologies that reduce carbon intensity and pollutants, and
3. Methods to de-risk the acceptance of a new energy technology.

The Homeland Security Goals in three strategic priority areas:

1. Artificial intelligence (AI) security,
2. Software understanding, and
3. Cyber/physical data fusion.

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Global Security (GS)

Overview

The Global Security (GS) Mission Foundation sponsors research advancing Sandia's ability to deliver technical innovation that advances security and peace around the world. The resurgence of great-power competition, the war in Ukraine, rapid increases in capability with corresponding reductions in cost for commercial technology are among the contemporary environmental drivers for GS missions.

For more information, a description of the Global Security Program Area at Sandia can be found on this webpage.

Keywords

- Sensors
- Detection
- Data Fusion
- Modeling & Simulation
- Countering Weapons of Mass Destruction (WMDs)

Key Research Foci for the FY25 LDRD Call

- **Global Monitoring**
  - Analytics for earlier detection including heterogeneous data fusion
  - Techniques to facilitate command and control of large satellite constellations
  - Methods to assess the integrity of low latency data streams
  - Research to enable an understanding of the underlying physics of lightning impacting properties of optical emission.
  - Advanced optical sensor ROIC design approaches that could realize lower power consumption, higher data rates, clock distribution, and improved processing performance
- **Global Nuclear Integration**
  - Research supporting future monitoring and verification needs for arms control and safeguards agreements
  - Innovations addressing proliferation from emerging tech
- **Security Systems of Systems**
  - Improve efficiency, efficacy, and lower lifecycle costs for the physical protection of sites and assets
  - Novel approaches to detect and characterize intrusion/insults to fixed sites or mobile transport while minimizing nuisance alarms
  - Methods for implementing and countering uncrewed systems (UxS)
  - Computational methods to automate and accelerate large, complex, impact simulations
- **Respond to Weapons of Mass Destruction (WMD) Risks**
  - Rapid identification, assessment, and defeat of chemical, biological, radiological and nuclear (CBRN) WMDs
  - Mitigating impacts of mis/disinformation during response
  - Consequence management and decision-making tools
  - Approaches to chemical and biological safeguards and security

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National Security Programs (NSP)

Overview

The National Security Program Mission Foundation funds innovative R&D that enables trusted, threat-informed, pathfinder technologies and systems across four domains to provide Integrated Deterrence and Defense options for the Nation: Cyber Innovation; Heterogeneous Integration & Trusted Strategic Radiation-Hardened Microsystems; Innovation for Proliferation Assessment; and Radiation Frequency Supremacy & Hypersonics.

For more information, a description of the National Security Program Area at Sandia can be found on this webpage.

Keywords

- Cyber
- Heterogeneous integration
- Autonomous Sensing
- Threat detection, assessment
- Radio frequency
- Hypersonics

Key Research Foci for the FY25 LDRD Call

The CYBER focus area applies science and engineering principles to understand and enhance the secure operation of complex, high-consequence national security systems in adversarial environments. We seek innovative proposals to address all aspects of the systems stack including hardware, software, complex systems and data with an emphasis in the following areas:

- Cyber risk and resilience
- Cyber assured and secure design
- Automated systems understanding (HW/SW)

The Heterogeneous Integration & Trusted Strategic Radiation-Hardened Microsystems (HI&TRH) focus area seeks solutions to integrate diverse technology components into a higher-level microsystem assembly with improved performance and optimal space, weight, and power for trusted and/or radiation-hardened applications.

- Heterogeneously Integrate Microsystems

Innovation for Proliferation Assessment (IPA) is focused on identifying multidisciplinary approaches for revolutionizing the detection, assessment, and response to current and future threats.

- Autonomous sensing systems and analysis to include data analytics
- Simulation and data analytical tools that extract signposts, indicators, and trends

The Radiation Frequency Supremacy & Hypersonics (RFS&H) focus area needs to understand the various effects of system design, components and materials on hypersonic and sensor systems.

- Architectures and advancements that improve performance in SWAP-constrained RF hardware
- Hypersonics
- Decision Analytics and Modeling/Simulation for RFS&H

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Nuclear Deterrence (ND)

Overview

A description of the Nuclear Deterrence Program Area at Sandia can be found on this webpage.

Key Research Foci for the FY25 LDRD Call

- Form factor Flexibility for Standard Weapon Functions
- Technologies for Common Interfaces to include new DOD Interfaces
  - Optical Components
- Anticipated Technology Needs to Address 'Emerging Threats'
  - Advanced COTS
  - Advanced Positional Awareness
  - Advanced RF
  - Inherently Robust Design
  - Next Generation Microelectronics
  - Secure Processor
- Commoditization of Weapon Functions to Streamline and/or Accelerate Product Realization
  - Advanced Manufacturing
- General Capabilities
  - Next Generation Safety
  - Next Generation Surety
- Cross Cutting Technical Focus Areas
  - Cyber/Trust
- Advanced Barriers
- Artificial Intelligence for Processing Augmentation of Weapon Program Phases and Sustainment

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