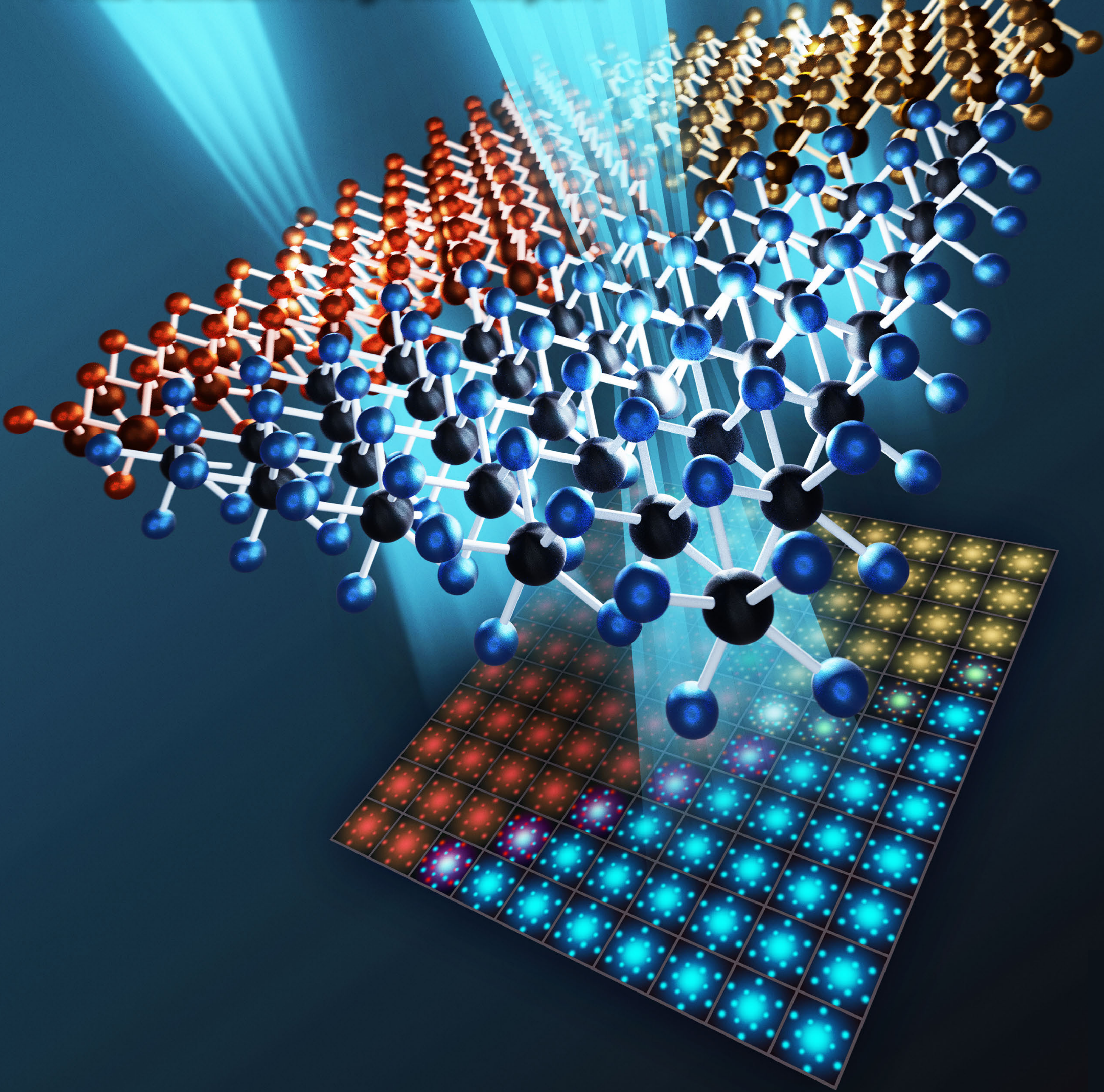
Los Alamos National Laboratory

Laboratory Directed Research and Development Program

FY22 Annual Progress Report



Los Alamos
NATIONAL LABORATORY

LDRD
LABORATORY DIRECTED
RESEARCH & DEVELOPMENT

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LABORATORY DIRECTED
RESEARCH & DEVELOPMENT
WHERE INNOVATION BEGINS

FY22 Annual Report

Structure of this Report
The Laboratory Directed Research and Development (LDRD) Annual Report for fiscal year 2022 (FY22) is organized as follows:

Overview: A description of the LDRD program at Los Alamos National Laboratory (LANL), including the program's structure and objectives; a summary of the program's value; and highlights of outstanding program accomplishments.

Project Summaries: The project summaries are organized by Capability Pillar – Complex Natural and Engineered Systems, Information Science and Technology, Materials for the Future, Nuclear and Particle Futures, Science of Signatures, and Weapons Systems. Project summaries for continuing projects appear first, followed by project summaries and technical outcomes for projects that ended in FY22.

The project summaries are compiled in a stand-alone document and are available by clicking the link below.
LDRD FY22 Compendium of Project Summaries

On the Cover
Cover Image: This image shows the overall concept of a capability developed in LDRD project 202204856MFR led by Michael Pettes. Image shows a four-dimensional scanning transmission electron microscopy. Artwork by Sarah Tasseff of Los Alamos National Laboratory

On the Inside Cover
National Security Sciences Building, Los Alamos National Laboratory. Photo credit: LANL

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Leadership Perspectives

LAURA STONEHILL, LDRD PROGRAM DIRECTOR

This is my fourth year with the Laboratory Directed Research and Development (LDRD) Program, and I am now one year into my role as the LDRD Program Director. Under my leadership, LDRD continues to strengthen the technical vitality, mission agility, and workforce development of Los Alamos National Laboratory (LANL) through the funding of innovative research and development.

The LDRD program plays a critical role in helping LANL meet our top strategic priorities. LDRD funding ensures that LANL can advance research and investment that addresses current and future challenges relevant to LANL missions. LDRD-funded projects are characteristically cutting-edge science, supporting LANL researchers who are developing innovative solutions to world problems, and helping LANL attract, develop, and retain a strong and talented workforce.

LDRD projects also contribute to the commercial market. This year, six projects with LDRD roots received 2022 R&D 100 awards, which recognize the projects as important and creative innovations in research.

Every year, LDRD holds competitive proposal calls that seek novel and transformative research and development (R&D) from across the Laboratory. Our rigorous proposal review processes ensure that selected projects embrace the high-risk, high-reward nature of LDRD and align with LANL mission, strategy, and investment priorities. Proposals are thoroughly reviewed through peer-review processes that assess technical merit, innovation, and feasibility using criteria derived from the LDRD objectives of technical vitality, mission agility, and workforce development. Once started, a carefully crafted project appraisal process ensures that projects are well managed and supported to maximize their potential for transformative R&D and impact. This year we adjusted the timeline of our Directed Research proposal call, moving the call up by approximately two months. This adjustment provides Principal Investigators with more time to prepare their proposals and, if awarded, provides additional hiring time prior to project start. In FY 2022, LDRD funded 455 research projects, with 193 of those projects being newly started projects.

We are excited to share our Annual Report with you. The report provides an overview of the exciting new research funded by our LDRD program and highlights recent accomplishments of Los Alamos National Laboratory's talented R&D staff.

Leadership Perspectives

JACOB WALTZ, LDRD DEPUTY PROGRAM DIRECTOR

I joined the Los Alamos LDRD Program Office as the Deputy Program Director in July of 2022 and had been involved with LDRD as a principal investigator (PI) and proposal reviewer for approximately 10 years prior to that. I have always been impressed with the breadth of research that LDRD supports in response to a wide range of scientific and national security challenges. In FY22, LDRD-funded projects had national impact in both basic science and applied areas such as space technology, clean energy, global threat reduction, public health, and nuclear security. LDRD has a prominent role in helping to build the future of the Laboratory, project by project and researcher by researcher.

As Deputy Program Director, I share in the formulation, implementation, and strategic direction of LDRD, and work closely with the Laboratory and external leadership at all levels. I am struck by the degree of rigor that LDRD uses to ensure and support quality projects, throughout the selection-execution-transition lifecycle.

The LDRD program funds projects that tend to be at the forefront of science. These projects attract world-class researchers, including postdoctoral researchers. Keeping with historic trends, LDRD supported more than half of the postdoctoral researchers at LANL in 2022. Mentorship is a critical component of the LDRD program. Laboratory senior scientists and advisors staffed on LDRD projects encourage early career staff and students to pursue new ideas and explore new research directions, thereby helping to increase retention and infuse new research talent across all areas of the Laboratory.

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Program Description

LDRD DIRECTIVES, OBJECTIVES, AND STRATEGIC CHALLENGES

Laboratory Directed Research and Development (LDRD) helps Los Alamos National Laboratory solve national security challenges through excellence in mission-focused science, technology, and engineering. The Department of Energy (DOE) Laboratory and Site-Directed Research and Development programs are among the most impactful sources of research and development for our Nation. The heart of the LDRD program is high-risk, high-reward research that creates innovative technical solutions for some of the Nation's most difficult challenges. The LDRD programs follow strategic guidance derived from the missions of the U.S. Department of Energy, the National Nuclear Security Administration (NNSA), and the Laboratory.

To execute that strategy, the Los Alamos LDRD program creates a free market for ideas, drawing upon the creativity of the Laboratory's best and brightest researchers. The combination of strategic guidance and grassroots competition provides a continual stream of capabilities that position the Laboratory to enable agile responses to national security challenges.

Funded with five to six percent of the Laboratory's operating budget, the LDRD program makes it possible for our scientists and engineers to pursue cutting-edge research and development in support of mission. This in turn helps the Laboratory, and the Nation, maintain its position of scientific and technological leadership.

LDRD objectives guide the overall program and align with DOE Order 413.2C Chg1. The LDRD program has three objectives: Technical Vitality, Mission Agility, and Workforce Development.

Technical Vitality

Advance the frontiers of science, technology, and engineering.

Mission Agility

Enable agile responses to national security challenges.

Workforce Development

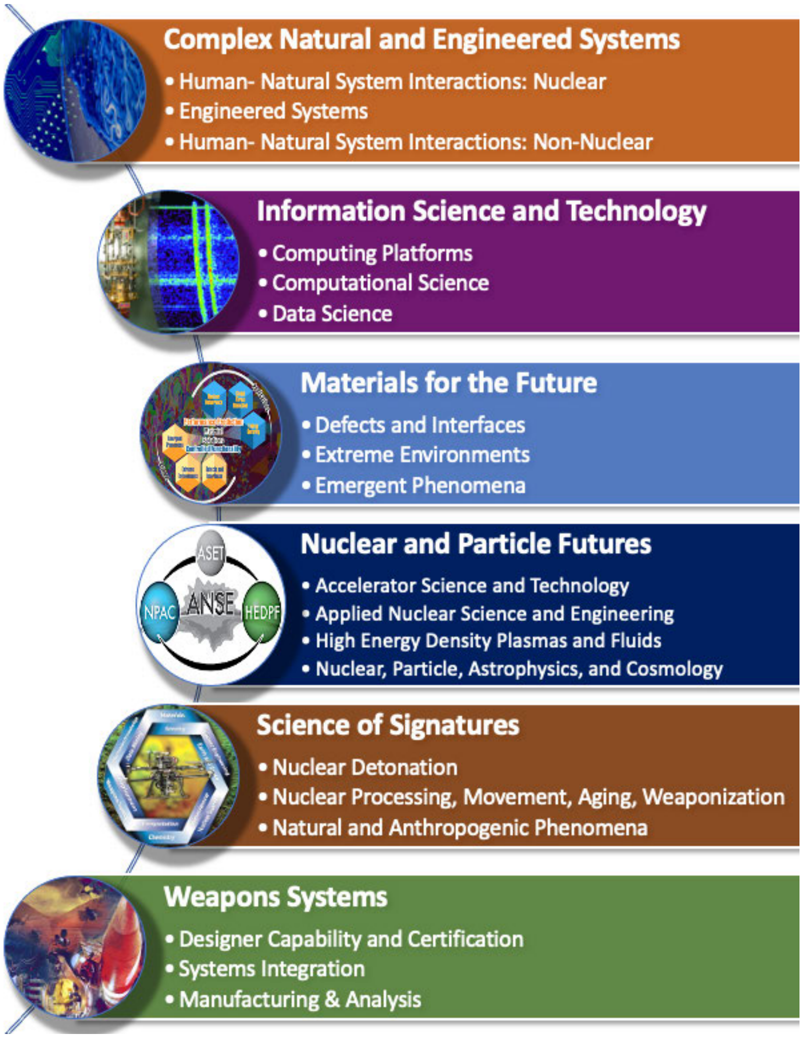
Attract, develop, and retain tomorrow's technical workforce.

The LDRD program responds to four national security challenges identified in the Strategic Framework (and derived from the 2018 Nuclear Posture Review). This report will illustrate the Los Alamos LDRD program's successes in responding to the LDRD objectives and the national security challenges listed below:

1. *Provide an agile, flexible, and effective nuclear deterrent.*
2. *Protect against all weapons of mass destruction threats.*
3. *Deter and defend against threats in multiple domains.*
4. *Strengthen our energy and environmental national security.*

LDRD ALIGNS WITH LABORATORY STRATEGY

The Laboratory's Capability Pillars define strategic investment areas at Los Alamos for present and future missions. All LDRD investments are aligned with the Capability Pillars.



Complex Natural and Engineered Systems
- Human- Natural System Interactions: Nuclear
- Engineered Systems
- Human- Natural System Interactions: Non-Nuclear

Information Science and Technology
- Computing Platforms
- Computational Science
- Data Science

Materials for the Future
- Defects and Interfaces
- Extreme Environments
- Emergent Phenomena

Nuclear and Particle Futures
- Accelerator Science and Technology
- Applied Nuclear Science and Engineering
- High Energy Density Plasmas and Fluids
- Nuclear, Particle, Astrophysics, and Cosmology

Science of Signatures
- Nuclear Detonation
- Nuclear Processing, Movement, Aging, Weaponization
- Natural and Anthropogenic Phenomena

Weapons Systems
- Designer Capability and Certification
- Systems Integration
- Manufacturing & Analysis

The Capability Pillars define six key a
science, technology, and engineering
which the Laboratory must lead in or
meet the national security challenges
today and tomorrow.

Program Structure

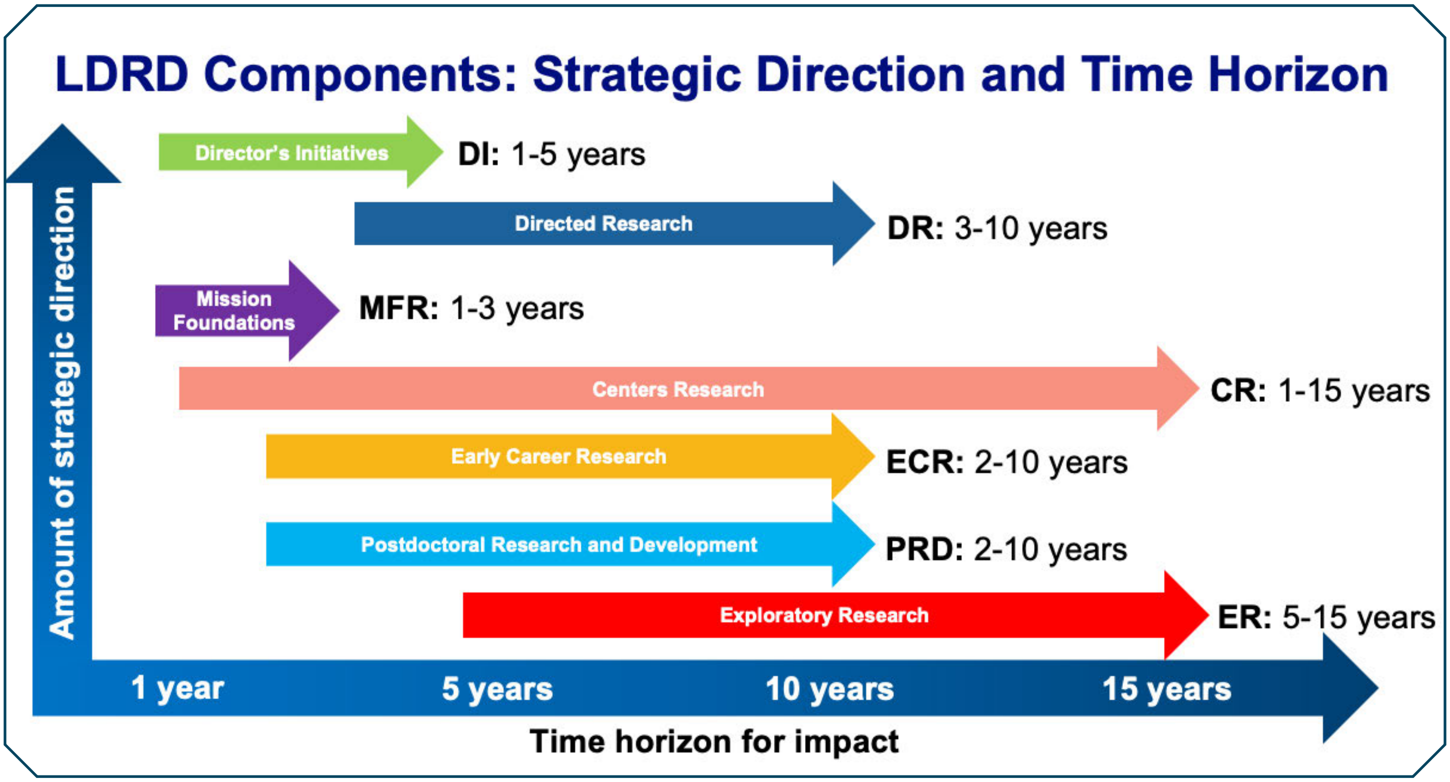
OVERVIEW

The Los Alamos LDRD program is organized into seven components with distinct institutional objectives:

- *Directed Research* (DR), flagship investments that create multidisciplinary solutions to complex problems defined by Lab strategy.
- *Exploratory Research* (ER), innovate at the frontiers of technical disciplines.
- *Director's Initiatives* (DI), invest in the Lab Agenda with the rigor and creativity of LDRD.
- *Mission Foundations Research* (MFR), translate discovery into novel mission solutions.
- *Early Career Research* (ECR), develop next-generation technical leaders.
- *Postdoctoral Research and Development* (PRD), attract and recruit top-quality talent into the Lab's pipeline.
- *Centers Research* (CR), incubate emerging ideas and talent in areas defined by the Lab's Strategic Centers.

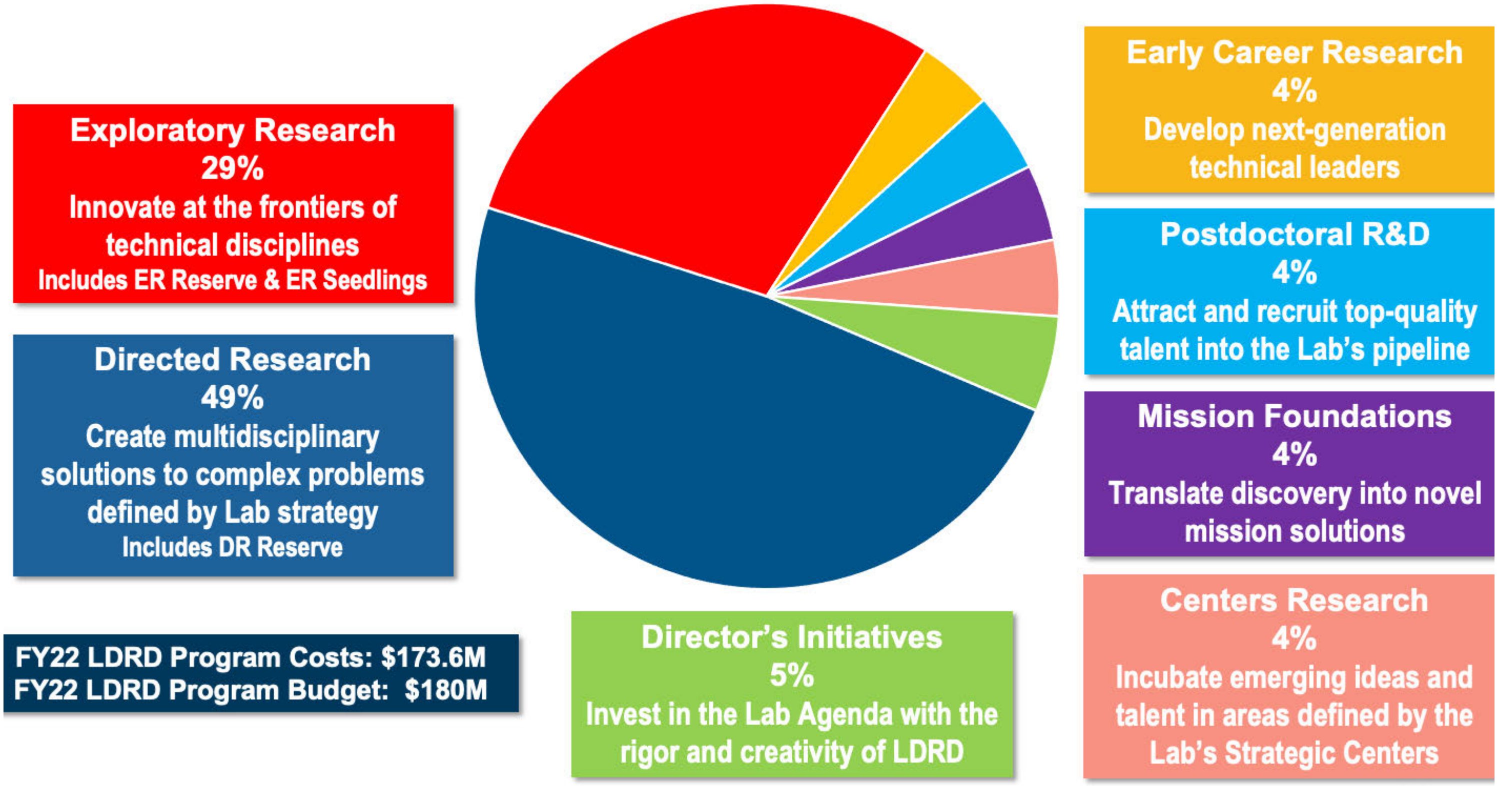
The amount of investment in each component is intentionally planned to balance the overall LDRD portfolio in both the time horizon for impact from LDRD projects and the amount of strategic direction from Laboratory leadership that is involve in the selection of projects.

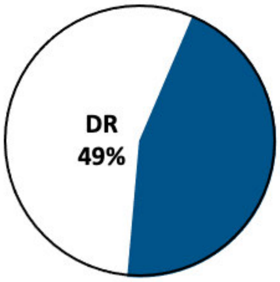
All seven components are discussed in further detail in this report.



In FY22, the LDRD program allocated $180M to 455 projects that incurred total costs of $173.6M. These projects were selected through rigorous and highly competitive peer review processes and are reviewed formally and informally throughout the fiscal year.

Funds were intentionally distributed across the seven LDRD components. The graphic below illustrates the distribution of funds by showing the total percentage of funds invested in each component area.





DIRECTED RESEARCH: CREATE MULTIDISCIPLINARY SOLUTIONS TO COMPLEX PROBLEMS DEFINED BY LABORATORY STRATEGY

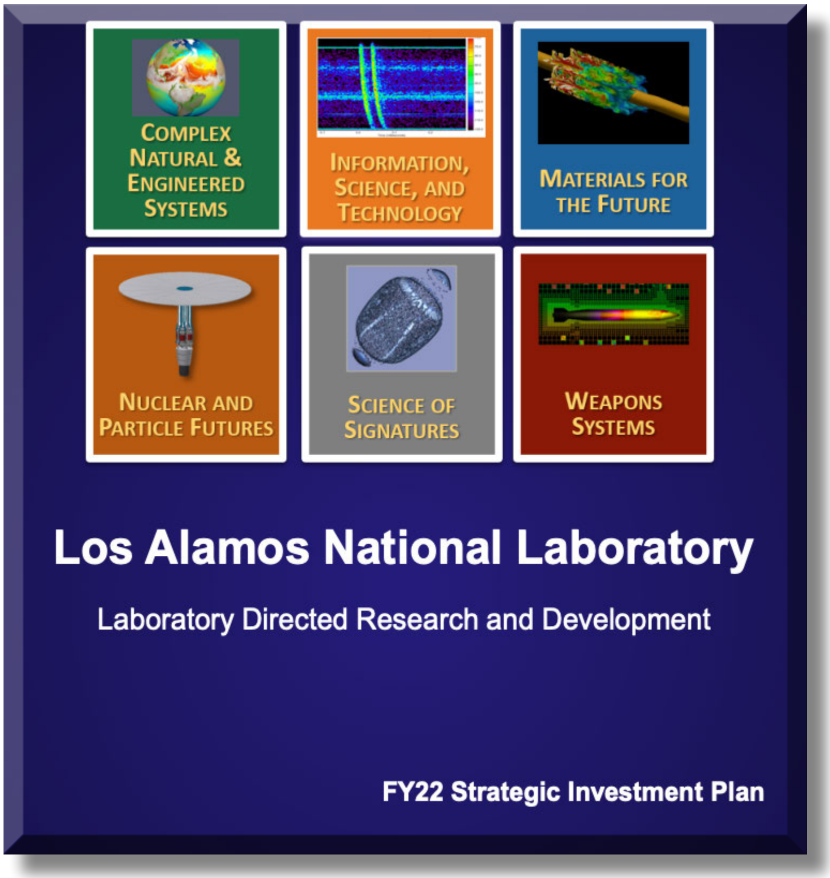
In FY22, LDRD funded 59 Directed Research projects, investing $84.2M, which represents 49% of the program's research funds.

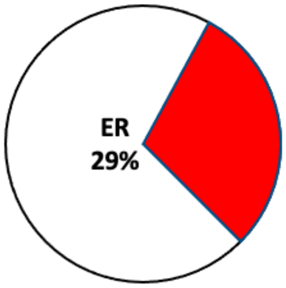
The Directed Research (DR) component is LDRD's flagship investment. This component focuses on long-range investments in multidisciplinary projects. DR projects are aligned to key competency or technology-development areas vital to LDRD's long-term ability to enable the Lab to execute its missions. Funding for individual DR projects is approximately $2M per year for three years.

The annual planning for DR directly ties to the Laboratory's Capability Pillars. This planning is communicated through the Strategic Investment Plan (SIP) which is published annually. SIP Development Teams associated with each Pillar lead a process of engaging broadly with the Laboratory to identify investment priorities for the upcoming fiscal year that are consistent with and supportive of the long-term Pillar strategy. Priorities within each Capability Pillar are set in order to maintain a balanced LDRD-DR portfolio that is in support of the Laboratory's capability goals.

While the SIP is strongly aligned with respective Pillar strategies, the SIP has a narrower focus than that of the overall Pillars, due to considerations such as urgency of need, timeliness of opportunity, and LDRD-DR portfolio balance considerations. Further, the SIP is responsive to both internally perceived capability gaps and to emerging strategic directions identified by the National Nuclear Security Administration (NNSA) and agency-specific strategies.

Priorities may include not just strategic capabilities, but also mission challenges requiring new and innovative approaches. Based on these priorities, staff submit proposals for peer review in a two-stage process that includes both technical and strategic review by separate panels.





EXPLORATORY RESEARCH: INNOVATE AT THE FRONTIERS OF TECHNICAL DISCIPLINES

In FY22, LDRD funded 195 Exploratory Research projects, investing $50.7M which represents 29% of the program's research funds.

The Exploratory Research (ER) component is focused on building technical staff competencies in key strategic disciplines that ready the Lab to address current and future national missions. Initiated by technical staff from across the Laboratory, ER projects explore highly innovative ideas in Technical Categories that underpin Laboratory missions. Funding for individual ER projects is approximately $350K per year for three years.

Exploratory Research is the most important channel for purely bottom-up creativity at the Laboratory. Unlike DR, there is not a guiding strategic document written specifically for ER. Instead, this component of the program is operated as an open and competitive path for every staff member to pursue funding for their leading-edge idea. While some ER technical work may have a less direct tie to Laboratory missions, the technical capability underpinning the work must be directly relevant to one or more Laboratory missions.

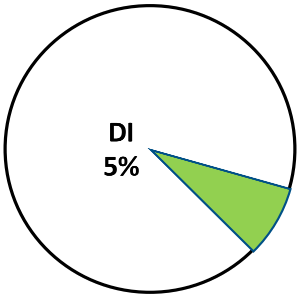
ER projects explore highly innovative ideas in 10 Technical Categories that support Laboratory missions.

Exploratory Research FY22 Technical Categories

- Advanced Materials Science and Engineering (AMSE)
- Atomic, Molecular, Quantum, and Optical Systems (AMQOS)
- Biological Sciences (BIO)
- Chemical Sciences (CHEM)
- Computational Methods and Computer Science (CMCS)
- Data Science and Mathematics (DSM)
- Earth and Space Sciences (ESS)
- Emergent Materials Behavior (EMB)
- High-Energy-Density Matter, Plasma, Fluids, and Beams (HPFB)
- Quarks to the Cosmos (QTC)

Exploratory Research- Seedlings

ER Seedlings projects are funded for 12 months at approximately $150K per project and are intended to address the most untested, high-risk aspects of a new idea so that, at the end of the project, the now researched and tested idea could then compete successfully for follow-on funding in any venue. The overall objective is to increase acceptance of high-risk proposals that would explore new concepts with the potential to transform the technical field.



DIRECTOR'S INITIATIVES: INVEST IN THE LABORATORY AGENDA WITH THE RIGOR AND CREATIVITY OF LDRD

In FY22, LDRD funded 25 Director's Initiative projects, investing $9.1M which represents 5% of the program's research funds.

LDRD Director's Initiatives (DI) tie directly to critical outcomes within the Laboratory Agenda. The senior Laboratory leaders (typically Associate Laboratory Directors) responsible for the Laboratory Agenda work with the LDRD Program Office and the Deputy Director for Science, Technology, and Engineering to identify strategic growth areas and potential projects. Proposals are held to the same standards of peer review as other LDRD investment components.

Associate Laboratory Directors (ALDs) typically begin planning before the start of the FY, communicating their project priorities to the LDRD Program Office. The LDRD Office follows with requests for individual proposals and peer review. Most initiatives for the year are in place by January. The duration of Director's Initiatives is between nine months and three years.

Lab Agenda Snapshot

January 2022 Update

Los Alamos NATIONAL LABORATORY

The Laboratory Agenda provides a structured framework that identifies the strategic objectives, critical outcomes, near-term R&D, and production and mission-support activities needed to accomplish our mission.

Strategic Objectives

Nuclear Deterrent
Lead the nation in evaluating, developing, and ensuring effectiveness of our nuclear deterrent, including the design, production, and certification of current and future nuclear weapons.

Threat Reduction
Anticipate persistent and emerging threats to global security; develop and deploy revolutionary tools to detect, deter, and respond proactively.

Technical Leadership
Deliver scientific discoveries and technical breakthroughs to advance relevant research frontiers and anticipate emerging national security risks.

Trustworthy Operations
Consistently demonstrate and be recognized by diverse stakeholders for trusted and trustworthy operations.

Critical Outcomes

Pit Production
Reconstitute optimized rate production of pits leveraging the nation's Plutonium Center of Excellence (Pu CoE) to support deterrence.

Non-Nuclear Production
Develop targeted non-nuclear production capabilities to address gaps in the national Nuclear Security Enterprise (NSE).

Computational Breakthroughs
Research, develop, and routinely apply world-leading computational methods, approaches, applications, and technologies to solve Los Alamos' most computationally challenging science and security problems.

Experimental Advances
Advance LANL's experimental characterization tools in conjunction with our computational advances to underwrite stockpile assessment without the need for a nuclear test.

Integrated Deterrence
Anticipate, develop, and demonstrate capabilities to solve emergent deterrence gaps.

Technology Modernization
Optimize and apply advanced technologies to enable modernization of the deterrent and its nuclear warheads.

Threat Response
Develop methodologies and tools, drawing on unique weapons capabilities, that influence international nonproliferation strategies, next generation arms control regimes, and technical solutions for counterterrorism, counterproliferation, and emergency response.

Quantum Leadership
Assert LANL leadership in the National Quantum Initiative; enable emergent scientific and national security needs by advancing quantum-relevant capabilities in materials, algorithms, simulation, and devices.

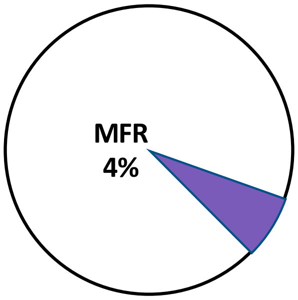
Biosecurity Preparedness
Enable national preparedness and response to infectious diseases and biosecurity threats by harnessing life sciences along with other innovative scientific approaches.

Climate & Clean Energy
Enable regional and national achievement of 2030/2050 climate and clean energy objectives through scientific, technological, and partnership innovations that build on established LANL capabilities.

Operational Capacity
Meet the capacity requirements necessary to perform current and future mission.

Culture Enhancements
Champion enhancements to our work environment that support inclusive staff engagement, respectful behaviors, and learning opportunities that are the foundation for safe, secure, compliant, and quality performance of our missions.

Force for Good
Be recognized as a force for good by Northern New Mexico communities and trusted by stakeholders to perform missions with minimal operational issues.



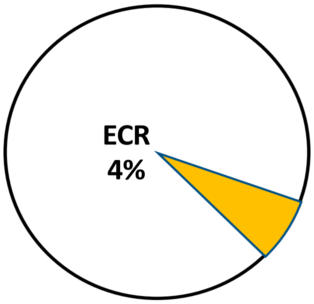
MISSION FOUNDATIONS RESEARCH: TRANSLATE DISCOVERY INTO NOVEL MISSION SOLUTIONS

In FY22, LDRD funded 26 Mission Foundations Research projects, investing $7.3M which represents 4% of the program's research funds.

Mission Foundations Research (MFR) is an intentional investment in applied science and engineering relevant to national security missions. The component was initiated in FY17 to address mission needs in the technology readiness level (TRL) 3-5 regime. Proposals must respond to "mission problem statements" reflective of mission needs across the Laboratory and are subject to rigorous peer review that assesses alignment with the LDRD program objectives– Technical Vitality, Mission Agility, and Workforce Development.

Staff propose solutions to the problems in an initial competition (Phase 1). Teams selected and funded through the Phase 1 call may later compete for continued Phase 2 funding. Phase 1 projects are expected to deliver significant R&D accomplishments, as well as demonstrate the feasibility of a more extensive project. At the end of the Phase 1 period, principal investigators (PIs)present their results through Phase 1 and submit proposals for Phase 2 as part of a competition to continue with Phase 2 funding. Projects not selected for Phase 2 conclude shortly after the down-select competition. MFR Phase 1 projects are funded at approximately $215K per project for 12 months with additional funding awarded for those projects selected to continue into phase 2.

Mission Research Area	FY22 Mission Problem Statement
Accelerators	Materials and Methods for LANL Accelerator Facilities, Projects, and Future High-Performance Accelerators
Energy	Nuclear and Applied Energy: Microreactors
Global Security	Nuclear Emergency Response: Nuclear Sensing for Field Operations Non-Traditional Threat Reduction
Weapons Engineering	Nuclear Explosive Package: Design, Manufacture and Characterization of Non-Special Nuclear Materials and Components for Advanced Delivery Platforms
Weapons Production-Including Actinide Operations	Agile and Efficient Nuclear Manufacturing: Primarily within the Los Alamos National Laboratory Technical Area (TA)-55 Plutonium Facility



EARLY CAREER RESEARCH: DEVELOP NEXT-GENERATION TECHNICAL LEADERS

In FY22, LDRD funded 54 Early Career Research projects, investing $7.2M, which represents 4% of the program's research funds.

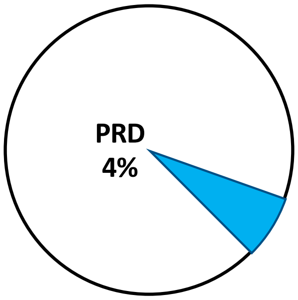
The Early Career Research (ECR) component of the LDRD program is designed to strengthen the Laboratory's scientific workforce by providing support to exceptional staff members during their crucial early career years. The intent is to support the development of early career researchers, aiding in the transition from postdoc or student to full-time staff member, and to stimulate research in disciplines supported by the LDRD program. ECR projects are individually funded up to $230K per year for two years. The number of ECR new starts roughly tracks with the Laboratory's hiring rate, which has been steadily high in recent years.

Early Career Research PIs must have received their highest degree within the last ten years and been hired as a Laboratory technical staff member no more than three years prior to the call.

Early Career Researcher ***Michael Peterson*** *made headlines when he detected two world-record lightning "megaflashes." The longest-distance flash was detected in the southern United States and spanned more than 477 miles from Mississippi to Texas. The longest-duration lightning strike was detected over Uruguay and lasted 17.1 seconds. These megaflashes are incredibly rare events.*

- *Read more about these megaflash events here*
- *View a simulation of the world record megaflash for largest extent here*

Michael's research was funded by LDRD project 20200529ECR, Using Thundercloud Illumination by Lightning to Understand Optical Signal Propagation in Nature.



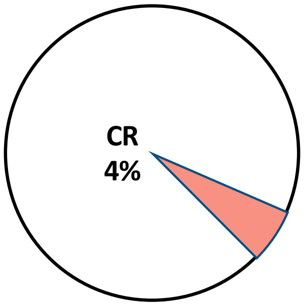
POSTDOCTORAL RESEARCH AND DEVELOPMENT: ATTRACT AND RECRUIT TOP-QUALITY TALENT INTO THE LAB'S PIPELINE

In FY22, LDRD funded 88 Postdoctoral Research and Development projects, investing $7.6M, which represents 4% of the program's research funds.

The Postdoctoral Research and Development (PRD) component of the LDRD program ensures the vitality of the Laboratory by recruiting early career researchers. Through this component, LDRD funds Postdoctoral Fellows to work under the mentorship of PIs on highly innovative projects. Postdoctoral projects are individually funded up to $200K per year for 2-3 years. The funding covers the postdoc full time in the first year, then part time in subsequent years to enourage the postdoc to engage with other Laboratory research. The review and selection processes are conducted under the auspices of the Los Alamos National Laboratory Postdoc Program Office.

***ChungHyuk Lee** was recently named a winner of the U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office Postdoctoral Recognition Award for 2022.*
Lee was honored for his work during a postdoctoral fellowship on the Fuel Cells and Electrochemical Sensors team within the Materials Synthesis and Integrated Devices group. His recognition is for research in high-performing and durable electrodes for proton-exchange membrane fuel cells.

Lee's research focused on designing and developing high-performing fuel cell cathodes by tuning their porosity, with the goal of yielding important insight into the transport properties of porous electrodes, guiding the next generation of electrode designs for electrochemical systems. This was also the topic of his LDRD work; 20210915PRD2, Pore Size and Wettability of Control Electrodes for Next Generation Hydrogen Fuel Cells. *Lee has published 25 peer-reviewed journal articles that have been cited more than 600 times.*



CENTERS RESEARCH: INCUBATE EMERGING IDEAS AND TALENT IN AREAS DEFINED BY THE LAB'S STRATEGIC CENTERS

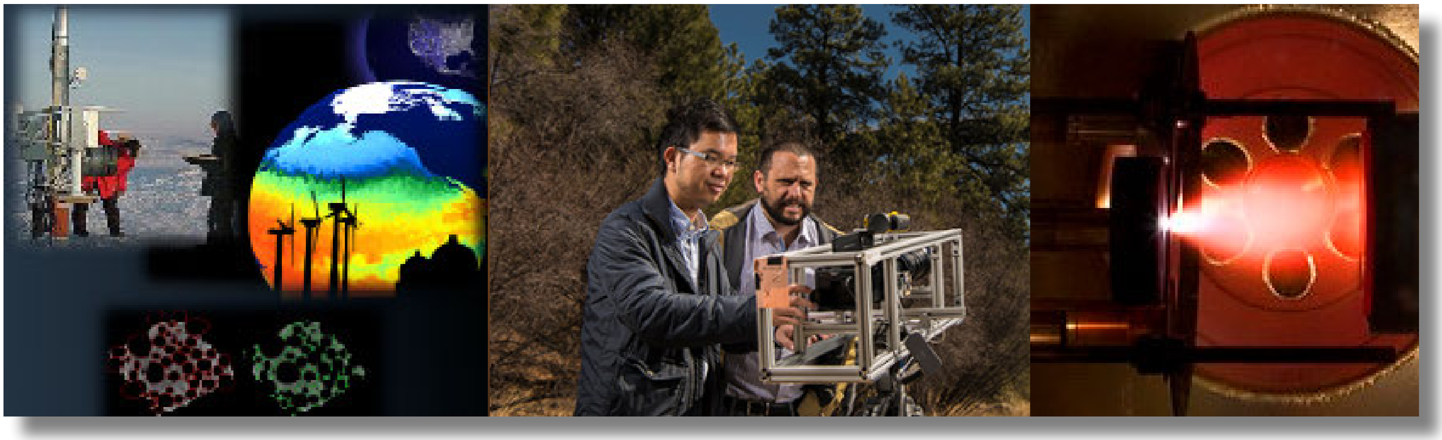
In FY22, LDRD funded 8 Centers Research projects, investing $7.2M, which represents 4% of the program's research funds.

To infuse new ideas and people into the Laboratory, LDRD has made a commitment to partner with the Lab's "Strategic Centers." The Centers Research (CR) component is focused on developing the Nation's next-generation workforce and leadership talent and serving as an incubator for the introduction of emerging science, technology, and engineering (ST&E) into Laboratory missions. CR projects are typically funded up to three years and single-year per project funding ranges from approximately $500K-$1,900K.

The Centers are organized under the National Security Education Center (NSEC), which supports a broad spectrum of interdisciplinary science that underpins the Lab's missions in national security. Collaborations established through the Centers provide Lab programs with new ideas, people, and contacts both inside and outside the Lab. For example, collaborative work with universities fosters top-quality research at the Lab in the more basic or fundamental aspects of fields that map into existing and/or emerging mission areas of the Laboratory. The Centers also introduce students and postdocs to the scientific interests of the Laboratory through educational internship and partnership programs to further the Laboratory's strategic goal of developing and mentoring the next-generation workforce of scientific and technical professionals.

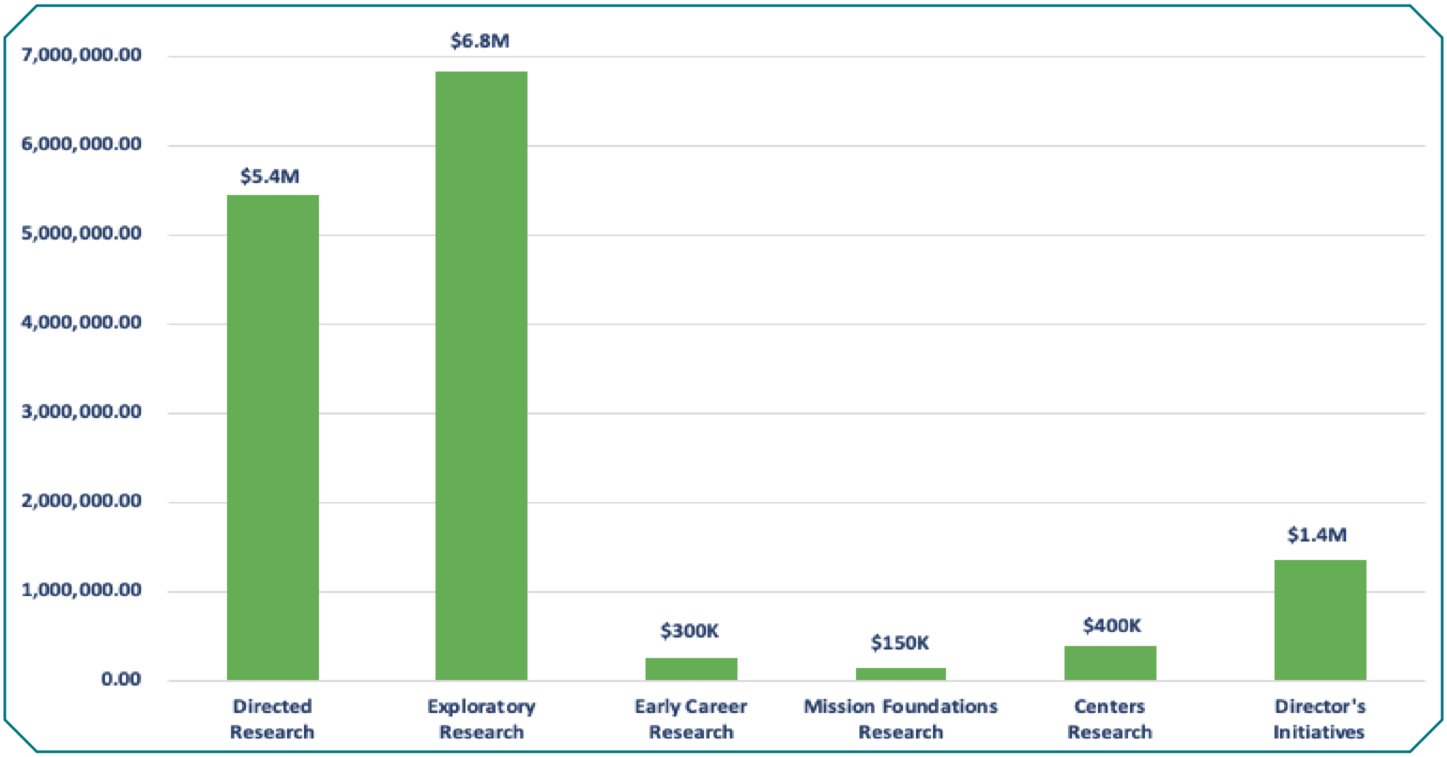
The Centers nucleate new research areas at the interface between emerging frontiers in the scientific community and the Laboratory's national security mission and are instrumental in anticipating future needs.

LDRD funds the Centers Rapid Response research and development program that supports short-term, rapid-turnaround high-risk ideas or feasibility studies. Three of the Centers have formal postdoctoral programs funded through LDRD, targeting strategic areas where new staff members are recruited at the PhD level.



RESERVE FUNDING

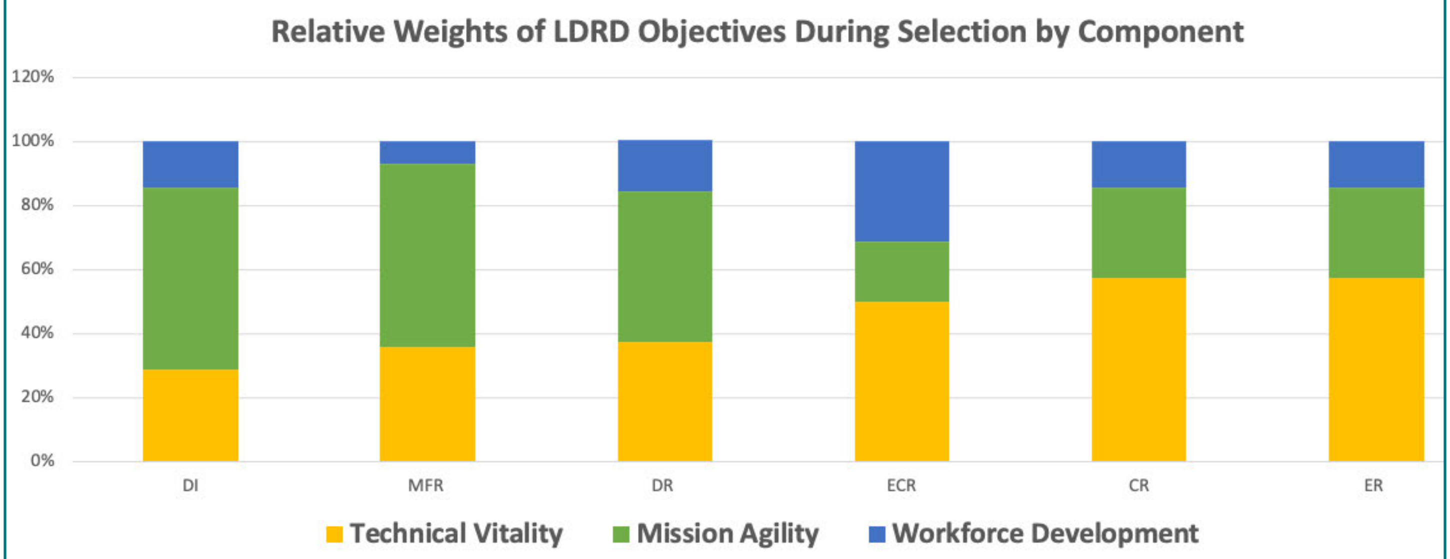
Not all of the LDRD budget is allocated to individual projects at the beginning of the fiscal year.
The LDRD program employs Reserve funding for strategic initiatives to facilitate institutional agility when addressing time-urgent, national security challenges.
When investing these Reserve funds, LDRD will typically turn to the Associate Laboratory Directors for guidance and priorities. Reserve proposals are held to the same peer review standards as the annual calls.
A total of $14.4M in Reserve funds were invested in FY22, with some funds added to exisitng projects and the remainder used to start 24 new projects during the year. The chart below shows how the funds were invested across the different LDRD components.



LDRD Objectives Across the Portfolio

LDRD strives for a portfolio that reflects all three LDRD objectives–Technical Vitality, Mission Agility, and Workforce Development. The balance has evolved and, considering the whole LDRD portfolio, mission relevance has a bit more weight than it did approximately five years ago. LDRD has also added explicit consideration of workforce development to proposal and appraisal criteria.

The LDRD Program Office puts thoughtful consideration into how the weighting of selection criteria for each component addresses the three LDRD objectives. The scoring matrix for each component states how the criteria are weighted.



Shown above is the share of selection criteria for each of the LDRD objectives for six of the seven LDRD components (PRD review and selection processes are conducted under the auspices of the Laboratory's Postdoc Program Office). The components form an integrated portfolio that balances the objectives. The purpose of mapping the criteria to the objectives is to ensure that both proposers and reviewers remain focused not only on the individual project, but also on how the project benefits the Laboratory and the Nation.

Program Value

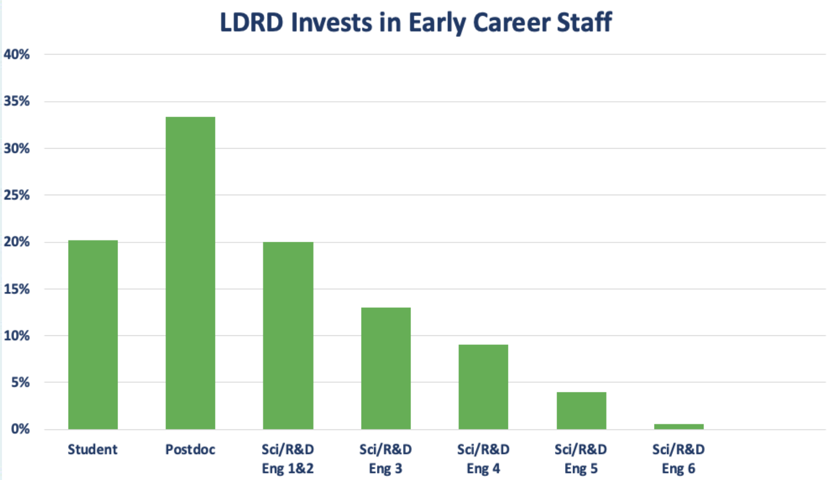
Congress established the LDRD program at the DOE National Laboratories in 1991 to foster excellence in science and technology and to ensure the Laboratories are technically vital and prepared to meet today's needs and tomorrow's challenges. LDRD achieves this by supporting high-risk, potentially high-payoff research and development.

The LDRD program is a key resource for addressing the science and technology goals of the Laboratory, as well as enhancing the scientific capabilities of Laboratory staff. Through careful investment of LDRD funds, the Laboratory builds its reputation, recruits and retains excellent scientists and engineers, and prepares to meet evolving national needs.

The programs' objectives are clear and crucial: Technical Vitality, Mission Agility, and Workforce Development.

FY22 LDRD Program Metrics

$174M	455	184
Total Program Cost	Total Number LDRD Projects	New LDRD Projects in 2022



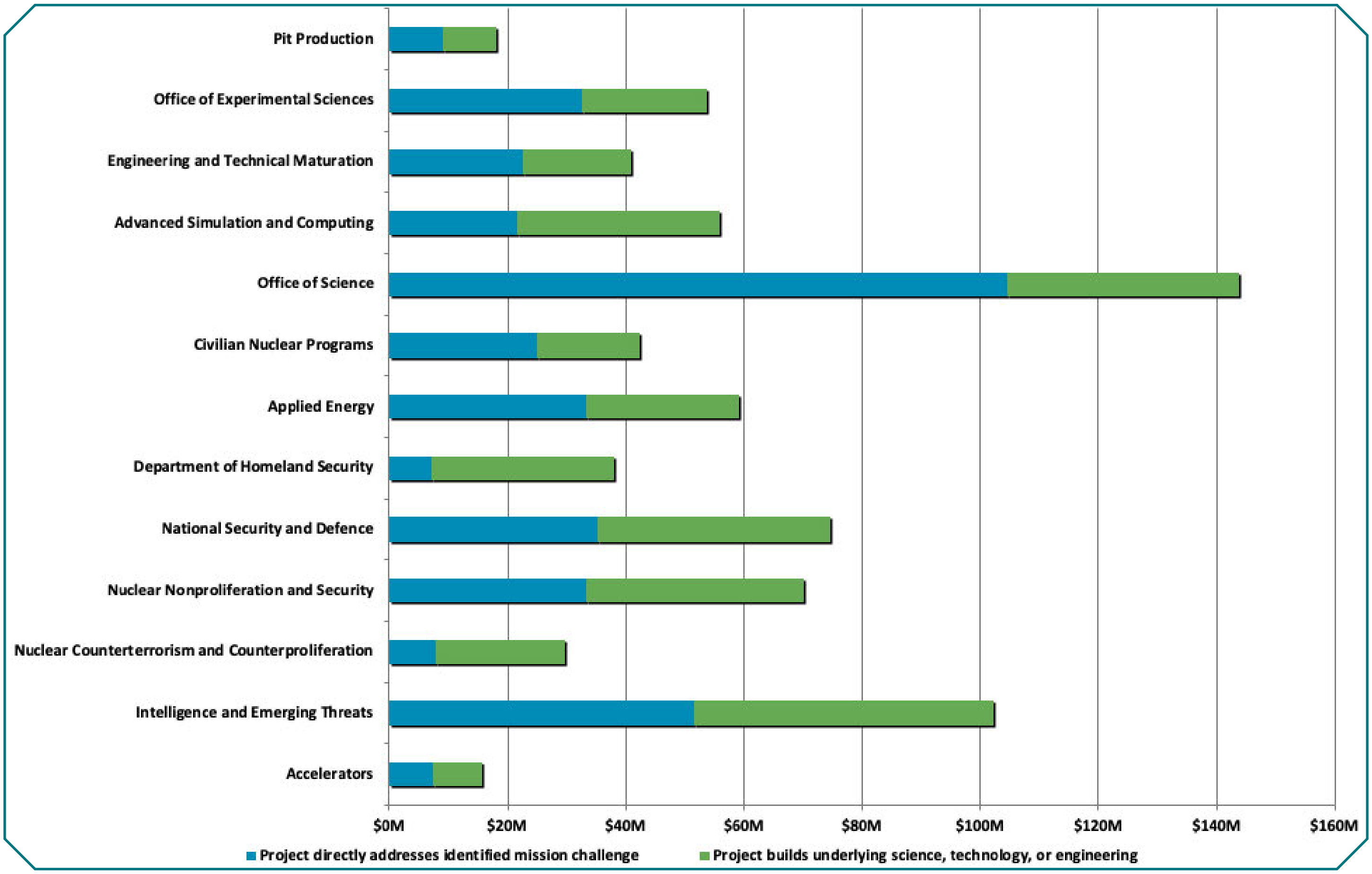
LDRD-supported Postdocs	60%	389 of 652 postdocs at LANL
LDRD-supported Postdoc to Staff Conversions	48%	58 of 120 conversions at LANL
Peer-reviewed Publications	40%	796 of 1,929 publications at LANL
U.S. Patents Issued	50%	19 of 38 patents at LANL
R&D 100 Awards	67%	6 of 9 R&D 100 awards at LANL

The metrics above show LDRD's impact on key performance indicators and measures. The bar graph, showing total hours charged to LDRD in FY22, illustrates the large engagement of early career staff, postdocs, and students in the LDRD program. As shown in the graph, 20% of the total LDRD labor hours were charged by students, 33% of the total were charged by postdoctoral researchers, and 20% of the total were charged by Scientists/R&D Engineers 1 & 2.

Mission Relevance

Mission relevance is one of the most important criteria in the evaluation of the LDRD program, as well as a potential LDRD project. It is carefully considered in project selection and tracked annually through the data sheet process. Many of the technologies that put Los Alamos on the map have deep roots in LDRD and are valuable to DOE and NNSA mission areas of nuclear security, energy security, environmental remediation, and scientific discovery and innovation. LDRD work also benefits the national security missions of the Department of Homeland Security, the Department of Defense, and other Federal agencies. As a result, the scientific advances and technology innovations from LDRD provide multiple benefits to all Los Alamos stakeholders, consistent with Congressional intent and the Laboratory's scientific strategy.

Mission Impact of the FY22 LDRD Portfolio ($M)



Los Alamos LDRD projects are required to address one or more mission areas. Investment in one project often contributes to and impacts multiple missions, thus the sum of the total LDRD investment in the relevant mission impact areas shown in the chart above is far greater than the annual LDRD budget.

Performance Indicators: LDRD at Los Alamos National Laboratory

This section presents both short and long-term performance indicators that LDRD maintains to evaluate the success of LDRD projects. LDRD yields well over its share of intellectual property, postdoc conversions, publications, patents, and technical awards.

INTELLECTUAL PROPERTY

An indication of the cutting-edge nature of research funded by LDRD is the contribution the program makes to the Laboratory's intellectual property. LDRD projects achieve a disproportionately large percentage of the patents and copyrights issued for Los Alamos research.

US Patents

Number of US patents issued in a given FY.
LDRD supported: Patents issued that would not exist if not for initial work funded by LDRD.

	FY18	FY19	FY20	FY21	FY22
LANL U.S. Patents	51	53	46	46	38
LDRD Supported	10	20	19	14	19
% Due to LDRD	20%	38%	41%	30%	50%

Software Copyrights

Number of software copyrights created in a given FY.
LDRD Supported: Copyrights issued that would not exist if not for initial work funded by LDRD.

	FY18	FY19	FY20	FY21	FY22
LANL Software Copyrights	113	147	119	120	115
LDRD Supported	19	16	39	48	47
% Due to LDRD	17%	11%	33%	40%	41%

Invention Disclosures

Number of declarations and initial records of an invention (a new device, method, or process developed from study and experimentation).
LDRD Supported: Disclosures issued that would not exist if not for initial work funded by LDRD.

	FY18	FY19	FY20	FY21	FY22
LANL Disclosures	109	118	115	101	73
LDRD Supported	40	39	34	33	30
% Due to LDRD	37%	33%	30%	33%	41%

SCIENCE AND ENGINEERING TALENT PIPELINE

In an increasingly competitive job market, LDRD remains an important vehicle for recruiting the brightest researchers to Los Alamos National Laboratory, where they become innovators and scientific leaders. LDRD is also instrumental in retaining new talent from the student and postdoc pool at the Laboratory.

Postdoctoral Researcher Support

Number of postdoctoral researchers working full- or part-time for the Laboratory.
LDRD supported: Postdoctoral researchers charging at least 10% of their time to LDRD.

	FY18	FY19	FY20	FY21	FY22
LANL Postdocs	556	632	655	665	652
LDRD Supported	281	376	363	391	389
% Due to LDRD	51%	59%	55%	59%	60%

Postdoctoral Researcher Conversions

Number of conversions from postdoctoral researcher to a member of the staff.
LDRD Supported: Conversion of postdoctoral researchers who charged at least 10% of their time to LDRD in the fiscal year preceding the conversion.

	FY18	FY19	FY20	FY21	FY22
LANL Conversions	81	87	75	81	120
LDRD Supported	37	39	35	44	58
% Due to LDRD	46%	45%	47%	54%	48%

Students Supported by LDRD

There are many opportunities for students to play important supporting roles on LDRD projects. A student may serve as a Co-Investigator on any LDRD proposal. For example, a student might work with an early career staff member on a project, where the early career staff member would serve as the PI and the student would serve a significant secondary role to that PI.

In FY22, 378 students worked at least 40 hours on LDRD projects. This compares to 333 students in FY21.

Through LDRD funded work on project *20220024DR, Fighting Fire with Fire: Enabling a Proactive Approach to Wildland Fire;* student Caleb Adams is improving fire behavior modeling's ability to estimate the impact a fire will have on vegetation.

PEER-REVIEWED PUBLICATIONS

The large volume of high-quality scientific contributions produced through LDRD funded work help the Laboratory maintain a strong presence and scientific reputation in the broader scientific community.

Publications

Number of peer-reviewed publications.
LDRD supported: Publications for which LDRD made a substantial contribution.

	FY18	FY19	FY20	FY21	FY22
LANL Publications	2,100	2,066	1,971	2,207	1,900
LDRD Supported	613	714	678	830	767
% Due to LDRD	29%	35%	34%	38%	40%

Citations

Number of times a peer review publication has been cited since the publication year.
LDRD Supported: Citations of publications for which LDRD made a substantial contribution.

Publication Year	FY18	FY19	FY20	FY21	FY22
LANL Citations	51,191	39,583	45,540	16,760	5,178
LDRD Supported	19,119	18,101	20,635	7,444	2,145
% Due to LDRD	37%	46%	45%	44%	41%

Three LANL researchers with strong ties to LDRD have been named 2022 highly cited researchers.

Victor Klimov *of Physical Chemistry & Applied Spectroscopy has been named a highly cited researcher every year since 2018. Victor began working with LDRD in 1998 as PI on an Exploratory Research Project.*

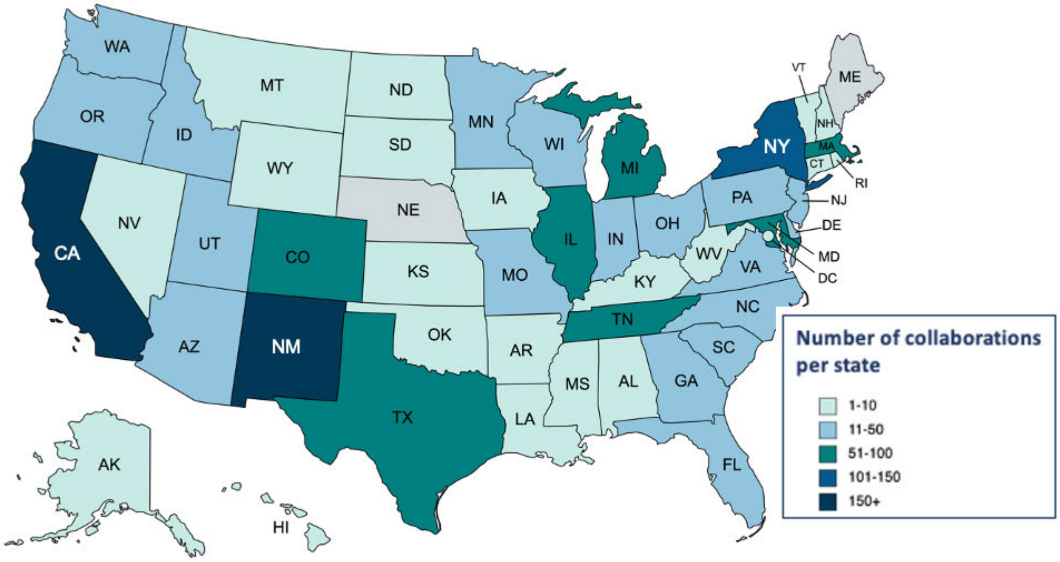
Wanyi Nie *of the Center for Integrated Nanotechnologies has been named a highly cited researcher twice before, in 2019 and 2021. Wanyi began working with LDRD in 2012 as a Co-Investigator on a Directed Research project.*

Piotr Zelanay *of Materials Synthesis and Integrated Devices made the list of highly cited researchers for the first time in 2022. Piotr began working with LDRD in 2004 as PI on a Postdoctoral Research Project.*

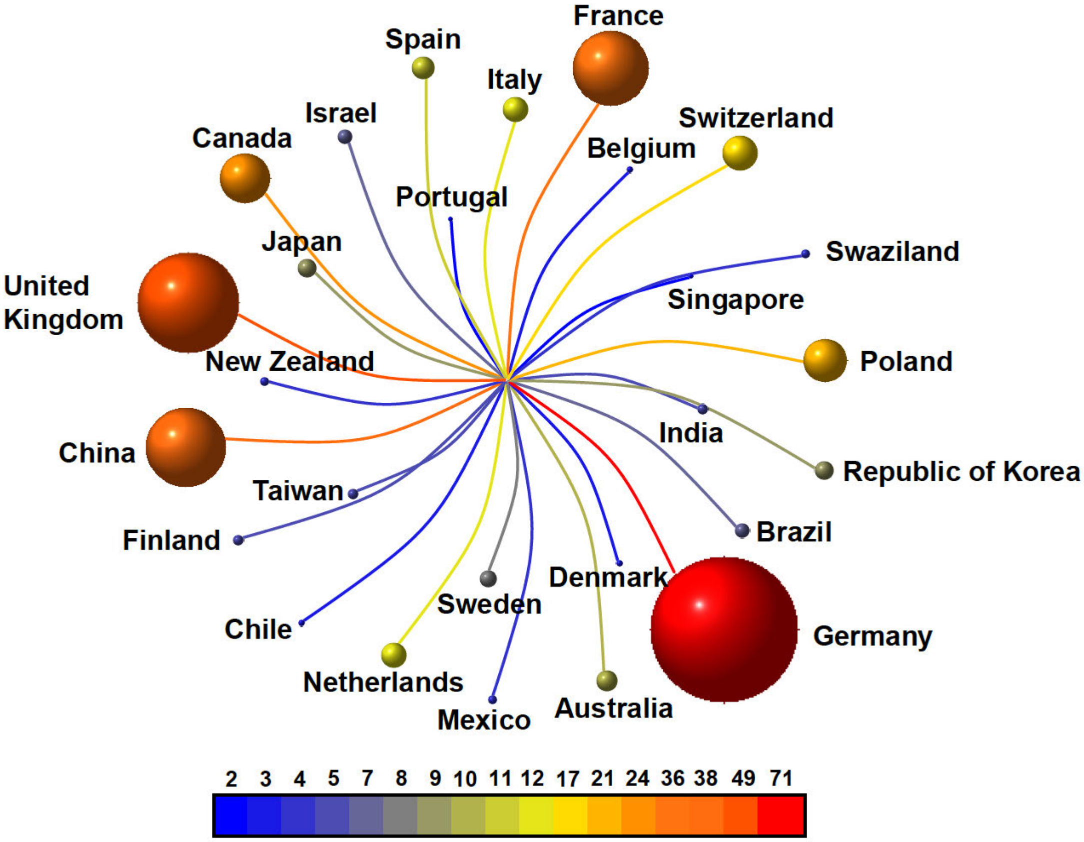
Pictured above are researchers Victor Klimov, Wanyi Nie, and Piotr Zelenay

BROAD INTELLECTUAL ENGAGEMENT

External collaborations are an essential part of the research and development in LDRD. By working with other national laboratories, academia, and industry, LDRD investigators are able to engage with experts across the Nation and around the world. External collaborations also allow for opportunities to access leading facilities. Most external collaborations under LDRD are on a no-exchange-of-funds basis, with collaborators using their own funding for the mutual benefit of working together and promoting scientific/engineering discovery.



In FY21 and FY22 LDRD researchers reported 1,887 external collaborations, including 1,488 collaborations with US scientists and engineers and 399 with foreign collaborators. Collaborations within the United States took place in 48 of 50 states.



The image on the left represents 27 countries in which foreign collaborations with LDRD researchers took place in FY21 and FY22. Circles ranging from smaller to larger indicate the number of collaborations per country, with the range starting at two and going up to 71 collaborations. Not pictured are 18 additional countries in which one collaboration per country took place.

THE LONG-TERM IMPACTS OF LDRD INVESTMENTS

The LDRD program is an investment in the Nation's future, ensuring mission support that is often realized after many years. This section highlights the longer-term (>5 year) impact of LDRD as a national asset. These performance indicators will be updated annually. As it is expected that the data may vary from year to year, long-term running totals will also be included and updated every 5 years.

Background

As part of a commitment to continuous improvement, representatives from each LDRD program at the NNSA Laboratories regularly participate in a working group to share best practices and discuss strategies for tracking the long-term impact of LDRD investments. In FY20, the working group finalized a combination of common quantitative and qualitative long-term indicators, emphasizing a systematic approach. Additionally, the working group recognized that the individual Laboratories may choose to report other long-term indicators that fit their unique missions and capabilities.

Alignment with LDRD Objectives

The collective selection of indicators (both numerical and qualitative) illustrate the long-term payoffs/success of LDRD, with respect to all three LDRD objectives (Technical Vitality, Mission Agility, Workforce Development). Because indicators crosscut objectives, there is not an intent to provide a 1:1 mapping of indicators with objectives.

Importance of Qualitative Data

The difficulty of developing numerical indicators for success in R&D programs is widely recognized. The metrics working group was able to develop numerical success indicators for both Technical Vitality and Workforce Development. "Success stories" were found to be more flexible to capture the successes in Mission Agility, as well as aspects of the other two LDRD objectives that are not well-captured by numerical metrics.

Tracing impact back to LDRD

Throughout this section, you will see references to "LDRD roots." There is often a lot of discussion with PIs about what it means for an accomplishment to have "LDRD roots." A simple case would be if an idea for an invention arises during an LDRD project and work on the invention is completed during the period of LDRD investment. But R&D often does not advance on such a short timescale. In general, an accomplishment (invention, paper, capability, etc.) is determined to have LDRD roots if there are one or more LDRD projects without which the accomplishment would never have come into being. In other words, if one can identify an LDRD project that was critical to the accomplishment, then it is considered to have "roots" in that LDRD project. Other relevant definitions for the metrics shared are included in the sections to follow.

SCIENCE AND ENGINEERING TALENT PIPELINE

Professional Fellows (American Physical Society)

One relevant indicator of advancement and leadership in an ST&E field is the election of individuals as Fellows of professional societies. This indicator reflects success for both the individual researcher and the Laboratory as a whole. American Physical Society (APS) Fellows were selected as the exemplar due to the important linkage of physicists with NNSA's core stockpile stewardship mission. Furthermore, APS Fellowship is awarded based on scientific merit and impact over an extended period of time. (In contrast, some professional societies may also award Fellow status based on service to the society.) Over the past 10 years, 87% of Los Alamos National Laboratory's (LANL) APS Fellows have had LDRD experience.

LDRD and American Physical Society Fellows at Los Alamos National Laboratory

	Single-Year Statistics			Five Years		To Date*
	FY20	FY21	FY22	FY13-FY17	FY18-FY22	FY13-FY22
Total Awards	6	3	3	34	21	55
Awards with LDRD Roots	5	2	2	31	17	48
% with LDRD Roots	83%	67%	67%	91%	81%	87%
Average Years from First LDRD Experience	12.2	15	14	11.04	13.18	11.79

Two LANL researchers elected 2022 APS Fellows have LDRD experience.

Nicole Lloyd-Ronning *was named an APS Fellow for her development and work on programs that introduce STEM science to students from elementary to undergraduate schools. Nicole's research at the Laboratory focuses on the physics behind the deaths of very massive stars and the black hole-accretion disks they create. She works on all aspects of these systems and studies how they fit into our broader understanding of star formation and the universe's cosmological evolution. Her work with LDRD first began in 2011 as a Co-Investigator on a Directed Research project.*

Rolando Somma *was selected as an APS Fellow for his theoretical contributions to quantum computing, in particular the development of quantum algorithms for quantum simulation. Rolando left Los Alamos in the fall of 2022 and is now working as a research scientist at Google. While at the Laboratory, he focused on quantum information theory, quantum computing, many body physics and beyond. He applied that expertise to the challenges of building reliable, large-scale, error-tolerant quantum computers capable of solving useful problems. Rolando's work with LDRD first began in 2005 as a Co-Investigator on a Directed Research project.*

Top 2%

The recognition of individuals as esteemed members of technical staff in an ST&E field is an indicator of career advancement. These staff members are named “Fellows” at LANL, Senior Scientists/Engineers at Sandia National Laboratory, and Distinguished Members of the Technical Staff (DMTS) at Lawrence Livermore National Laboratory. The shorthand name used here, “Top 2%,” comes from the intent at each of these Laboratories to limit membership to the top 1% or 2% of scientific and technical staff. Typically nominated and screened by a committee, the Top 2% are recognized for something similar to a lifetime achievement award, in this case, for contribution to the Laboratory’s mission.

In FY22, all nine of the LANL staff awarded the Fellow recognition had prior experience with LDRD. Fellows typically gain LDRD experience early in their careers, with an average of about 13 years from their first LDRD experience to being named a Fellow.

LDRD and Top 2% Fellows at Los Alamos National Laboratory

	Single-Year Statistics			Five Years		To Date*
	FY20	FY21	FY22	FY13-FY17	FY18-FY22	FY13-FY22
Total Awards	7	4	9	21	32	53
Awards with LDRD Roots	7	3	9	19	29	48
% with LDRD Roots	100%	75%	100%	90%	91%	91%
Average Years from First LDRD Experience	12.7	10	17.11	11.5	15.2	13.7

Nine LANL researchers elected 2022 Fellows have LDRD experience.

Babetta Marrone *of the Microbial and Biome Sciences group was named a Fellow for her high-level scientific achievement in the fields of bioenergy and biosecurity. Marrone has made numerous contributions to basic and applied research that impact the Laboratory’s national security programs in bioforensics and bioeconomy research. She is a recognized authority in biosciences and has served in national-level positions and on committees in related fields. Babetta’s work with LDRD first began in 2005 as a PI on an Exploratory Research project.*

David Chavez *of the High Explosives Science and Technology group was named a Fellow for his pioneering physical insights into synthetic organic chemistry for energetic materials, his innovations in the development of new explosives and his unwavering commitment to high-level intellectual achievements. Chavez plays a pivotal role in providing critical leadership in the energetic materials field for the nuclear weapons program and the broader defense and national security communities. David’s work with LDRD first began in 2006 as a Co-Investigator on an Exploratory Research project.*

(continued on next page)

Nine LANL researchers elected 2022 Fellows have LDRD experience.

Hui Li *of the Nuclear and Particle Physics, Astrophysics, and Cosmology group was selected as a Fellow for major discoveries in the field of plasma astrophysics. He is recognized as the main person to discover and fully explain Rossby wave instabilities and their role in transporting angular momentum in proto-stellar and protoplanetary disks, one of the most important physics issues in stellar and planetary formation. Hui's LDRD work first began in 2001 as a PI on an Exploratory Research project.*

Jianxin Zhu *of the Physics of Condensed Matter and Complex Systems group at Los Alamos was selected as a Fellow for his distinguished career using theory and computation to advance our understanding of the physics and electronic structure underlying strongly correlated materials, quantum materials, functional materials and actinides. These materials are at the center of current scientific research, with applications in energy security, nanotechnology, and platforms for quantum computing. Jianxin's LDRD work first began in 2005 as a Co-Investigator on a Directed Research project.*

Karissa Sanbonmatsu *of the Theoretical Biology and Biophysics group was named a Fellow for contributions to the development of large-scale computational models of biomolecular machines. Sanbonmatsu's cutting-edge work in furthering biological understanding through computational methods has been implemented on the most advanced high-performance computing platforms. Her work demonstrates and reinforces the profound scientific contributions of advanced computational methods and platforms in tackling complex, multi-scale numerical problems. Karissa's LDRD work first began in 2002 as a PI on an Exploratory Research project.*

Lin Yin *of the Laboratory's Plasma Theory and Applications group is one of the world's foremost experts on the physics of laser plasma interactions. She was named a Fellow for her important discoveries in the physics of laser scattering and energy coupling in inertial confinement fusion experiments on major laser facilities for the weapons program. She has also made groundbreaking discoveries in laser-driven ion acceleration using high-intensity short-pulse lasers, which have applications in society and national security. Lin's LDRD work first began in 2007 as a Co-Investigator on a Directed Research project.*

Neil Harrison *of the National High Magnetic Field Laboratory is an internationally recognized leader in the broad field of condensed-matter physics. He was named a Fellow for his pioneering work on the use of very strong magnetic fields to unravel the electronic structure of strongly correlated materials, most notably high-temperature superconductors, and for his discovery of the importance of electronic entropy in the phase stabilization of plutonium. Neil's LDRD work first began in 2004 as a PI on a Postdoctoral Research project.*

Ricardo Lebensohn *of the Fluid Dynamics and Solid Mechanics group was named a Fellow for his impact and recognition in the field of microstructure and property relationships of polycrystalline materials. His ideas and computational approaches drive the field and influence virtually everyone performing microstructure-aware computational modeling of polycrystalline materials. Lebensohn has had a tremendous impact on the Laboratory's mission and is recognized as an international authority by both the Laboratory and external scientific communities. Ricardo's LDRD work first began in 2010 as a Co-Investigator on a Directed Research project.*

Tim Germann *of the Physics and Chemistry of Materials group was selected for his distinguished career at the Laboratory, making seminal scientific contributions in a number of computational areas and serving in a number of leadership roles at Los Alamos and nationally. Germann is an internationally recognized authority for three main bodies of work: computational materials science, computational epidemiology, and computational co-design. Tim's LDRD work first began in 2005 as a PI on an Exploratory Research project.*

American Association for the Advancement of Science

Four Los Alamos scientists have been named Fellows of the American Association for the Advancement of Science (AAAS). Members have been awarded this honor by AAAS because of their scientifically or socially distinguished efforts to advance science or its applications. The honorees are Stosh Kozimor, Rangachary Mukundan, Tanja Pietrass, and Sergei Tretiak. Three of the four honorees have LDRD experience and are listed below.

Three LANL scientists named 2022 Fellows of the American Association for the Advancement of Science have LDRD experience.

Rangachary Mukundan*, formerly of the Materials Physics and Applications Division at Los Alamos, was honored for seminal contributions to the development of mixed potential electrochemical sensors and the development of accelerated stress tests for polymer electrolyte membrane fuel cells. His research interest includes fuel cells, electrolyzers, flow batteries and sensors. His current projects are focused on the durability of polymer electrolyte membrane electrolyzers and fuel cells. He is the co-inventor on eight U.S. patents and has authored more than 190 peer-reviewed journal and transaction papers, cited more than 10,000 times. In September 2022, he left Los Alamos to work as a senior scientist at Lawrence Berkeley National Laboratory. His LDRD work first began in 2012 as a PI on a Directed Research project.*

Sergei Tretiak *of the Theoretical Division was honored for distinguished contributions to the field of computational and theoretical chemical physics, especially for optical materials for next-generation energy systems, electronic properties of molecular structures and optoelectronics of low-dimensional materials. Sergei is also an American Physical Society Fellow and a Fellow of the Royal Society of Chemistry. He has also received the Humboldt Research Award, the Los Alamos Postdoctoral Distinguished Mentor Award and the Los Alamos Fellow's Prize for Research. Tretiak has published more than 400 articles, been cited nearly 30,000 times and presented more than 300 invited and keynote talks in the United States and abroad. Sergei's LDRD work first began in 2012 as a PI on a Directed Research project.*

Stosh Kozimor *of the Chemistry Division was honored for seminal contributions that have advanced fundamental science and solved applied problems in heavy-element chemistry, separations, isotope production and national security. Stosh serves as principal investigator for the Office of Science Heavy Element Chemistry Program and works with the Isotope Production team at Los Alamos. Together with his team, he has advanced fundamental science at the convergence of radio- and inorganic chemistry and has solved technical problems critical to Department of Energy missions in national security, isotope production, separations and heavy-element chemistry. Stosh's LDRD work first began in 2010 as a Co-Investigator on a Directed Research project.*

R&D 100 Awards

Another relevant indicator of advancement and leadership in an ST&E field is R&D 100 Awards. The prestigious “Oscars of Invention” honor the latest and best innovations and identify the top technology products of the past year. The LDRD Program Offices at each site often partner with sister organizations, such as the Intellectual Property Office and Public Affairs, to track whether R&D 100 winners (whether in the standard category or special awards) have “LDRD roots.” Because of the long development time from idea to practical implementation, the staff on a R&D 100 Award may not be the same staff who worked on the original R&D. Each site’s LDRD Program Office engages in an extensive interview process to uncover the details of how the LDRD work led to the celebrated invention.

In FY22, six of the nine R&D 100 Awards received by LANL have roots in LDRD. While there is sometimes minor fluctuation from year to year, multi-year analyses consistently reflect a high majority of R&D 100 winners with prior LDRD experience. At LANL, 38 of the 62 R&D 100 awards given to LANL since FY13 have roots in LDRD.

LDRD and R&D 100 Awards Earned by Los Alamos National Laboratory

	Single-Year Statistics			Five Years		To Date*
	FY20	FY21	FY22	FY13-FY17	FY18-FY22	FY13-FY22
Total Awards	8	7	9	21	32	62
Awards with LDRD Roots	6	4	6	13	25	38
% with LDRD Roots	75%	57%	67%	62%	78%	61%
Average Years from First LDRD Experience	4.67	3	9.33			

Why does this Matter?

LDRD enables scientists and engineers to advance fundamental science with many possible applications. In this way, LDRD is the spark that sets many achievements in motion. Identifying the LDRD roots in R&D 100 winners reflects the maturation of a concept from early R&D to an innovation with practical utility. The Laboratory technologies recognized by R&D 100 Awards often benefit many facets of society at-large.

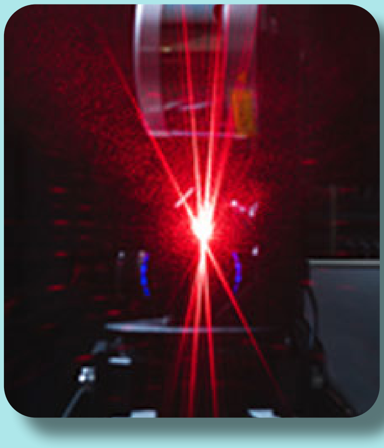
In 2022 Los Alamos led nine R&D 100 winners. Six of the awards have roots in LDRD. The following six awards are those with LDRD roots.

2022 R&D 100 WINNER

Additively Manufactured Tamper Evident Container

Additively Manufactured Tamper Evident Container is an electro/optical-mechanical system that secures items from disclosure and espionage. The technology uses additive-manufacturing techniques for concurrent creation of a container and arbitrarily complex-shaped three-dimensional (3D) tamper-sensitive features within its walls. Encrypted boards stored inside permanently record the complete security history of the protected items.

John Bernardin, Alessandro Cattaneo, Jack Gioia, Alexandria Marchi, and David Mascarenas led the team of Graham Arinder, Aaron Juntunen, Ryan Maki, Peter Meyerhofer, and Alexander Rose. Watch the video.



ASSESS: Acoustic Steady-state Excitation Spatial Spectroscopy

The full-structure, 3D nondestructive evaluation tool rapidly identifies subtle, hidden material defects, such as corrosion, cracking, and delamination, which can undermine structural integrity. ASSESS can inspect metals, plastics, composites, and additively manufactured components. The integrated field-deployable instrument leverages continuous ultrasonic excitation and laser Doppler vibrometry to perform inspections at stand-off distances.

The Los Alamos team consisted of Ian Cummings, Joshua Eckels, Peter Fickenwirth, Eric Flynn, Erica Jacobson, Matthew Luceadams, Alison Root, and Adam Wachtor. Watch the video.

BioManIAC: Bioplastics Manufacturing with Intelligent Adaptive Control

BioManIAC uses machine-learning models and polymer informatics to identify and optimize new biopolymer chemistries and physical properties. The technology screens millions of possible polymer combinations to save significant time and resources compared to trial-and-error of traditional R&D. BioManIAC revolutionizes the process of polymer design and optimization.

BioMANIAC also won also won the Bronze Medal Special Recognition Award for Market Disruptor-Services, which highlights a service that forever changed the R&D industry.

Joseph Dumont led the Los Alamos team of Carl Iverson, Babetta Marrone, and Ghanshyam Pilania. Watch the video.

2022 R&D 100 BRONZE

LightSlingers: Antennas that Generate Radio Waves from Faster-than-light Currents

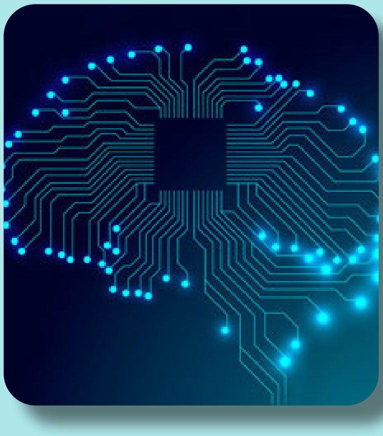
The novel type of broadband antenna "slings" tightly focused wave packets precisely toward a target location. Unlike conventional antennas, they use polarization currents, animated within a dielectric material to faster-than-light speeds, as their emission mechanism. LightSlingers provide better coverage, efficiency, bandwidth, and security than traditional antennas or phased arrays, in a sturdier package with far fewer components.

Andrea Schmidt and John Singleton led the Los Alamos team of Connor Bailey, Frank Krawczyk, Helen Lu, Kimberly Nichols, and James Wigger.

LightSlingers won the Gold Medal Special Recognition for Green Technology Award, recognizing innovations that help make our environment greener; and the Bronze Medal Special Recognition for Corporate Social Responsibility Award, which honors organizational efforts to be a greater corporate member of society. Watch the video.

2022
R&D 100
GOLD

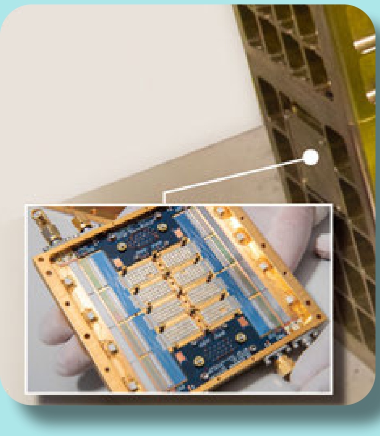
2022
R&D 100
BRONZE



On-Chip Neuromorphic Backpropagation Algorithm (ONBA)

Los Alamos National Laboratory, a member of the Intel Neuromorphic Research Community, developed the open-source ONBA to provide low-power machine learning (ML) on brain-like (neuromorphic) computers. The algorithm runs on Intel's Loihi chip, which emulates how the brain communicates via voltage spikes. Providing learning entirely on-chip greatly reduces power usage compared with standard computer architectures. Energy-efficient neuromorphic architectures decrease the carbon footprint of ML and support autonomous devices, such as drones, satellites, and robots.

Andrew Sornborger led the team of Alpha Renner, Forrest Sheldon, Jordan Snyder, Louis Tao, and Anatoly Zlotnik. Watch the video.



SOFIA: Spectrometer Optimized for Facility Integrated Applications

Nuclear technology, including nuclear power and nuclear medicine, needs safeguards to prevent the unintended spread of nuclear materials. SOFIA provides rapid nondestructive isotopic analysis of radioactive materials without taking a sample or even opening typical containers. SOFIA's simple infrastructure requirements and compact size are optimal for nuclear fuel cycle facilities, medical isotope production, and environmental monitoring laboratories.

Los Alamos led the joint entry of the National Institute of Standards and Technology (NIST) and the University of Colorado - Boulder. Mark Croce directed the Los Alamos team of Matthew Carpenter, Eric Feissle, Katrina Koehler, Daniel McNeel, David Mercer, Katharine Schreiber, Sophie Weidenbenner, and Ryan Winkler. Watch the video.

Additional LDRD Spotlights

Los Alamos National Laboratory's Bette T. Korber Named Among the Best Female Scientists in The World 2022 Ranking

Los Alamos National Laboratory Fellow Bette T. Korber, a computational biologist, has been named by Research.com as among the "Best Female Scientists in the World 2022 Ranking."

The primary areas of study that Korber focuses on are virology, virus, genetics, immunology, and epitope. Her research also integrates issues of viral evolution and antibodies, concentrating on AIDS vaccines and concerns with HIV antigens. Bette's LDRD work first began in 2005 as a PI on a Directed Research project. Read the article by Carol Clark.

Meet the Global Security Medal Winners

Sara Del Valle and Catherine Snelson have been awarded the 2022 Los Alamos Global Security Medal. The award recognizes the exceptional achievements of active or recently retired employees who have made significant contributions to the Laboratory's global security mission.

"Sara is a standout epidemiologist whose insights have led to better models for a number of diseases and health threats, while Cathy's expertise in seismology has enabled great advances in nuclear explosion monitoring," said Director Thom Mason. "Their work makes the world a safer and better place, which is a key aspect of Los Alamos National Laboratory's broad national security mission."

Sara's LDRD work first began in 2016 as a PI on an Exploratory Research project.
Cathy's LDRD work first began in 2017 as a peer reviewer on Exploratory Research and Directed Research peer review panels.

LDRD Program Accomplishments

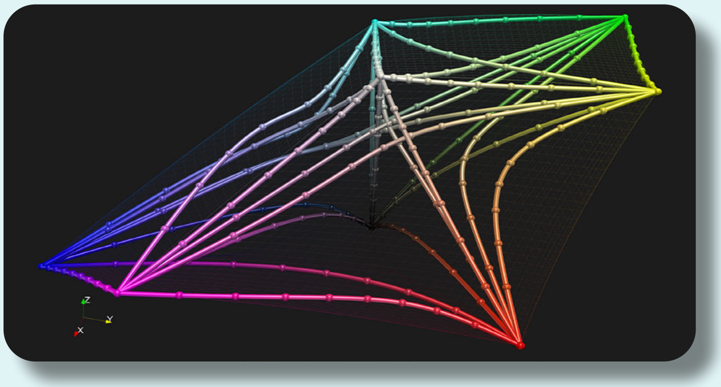
TOP SCIENCE IN THE NEWS

Math Error: A new study overturns 100-year-old understanding of color perception

A new study corrects an important error in the three-dimensional (3D) mathematical space developed by the Nobel Prize–winning physicist Erwin Schrödinger and others that has been used by scientists and industry for more than 100 years to describe how your eye distinguishes one color from another. The new research has the potential to boost scientific data visualizations, improve TVs and recalibrate the textile and paint industries.

"The assumed shape of color space requires a paradigm shift," said Roxana Bujack, a computer scientist with a background in mathematics who creates scientific visualizations. Bujack is lead author of a recent paper by a Los Alamos team on the mathematics of color perception. "Our research shows that the current mathematical model of how the eye perceives color differences is incorrect. That model was suggested by Bernhard Riemann and developed by Hermann von Helmholtz and Erwin Schrödinger — all giants in mathematics and physics — and proving one of them wrong is pretty much the dream of a scientist."

The team was surprised when they discovered they were the first to determine that the longstanding application of Riemannian geometry, which allows generalizing straight lines to curved surfaces, didn't work.



This visualization captures the 3D mathematical space used to map human color perception. Image credit: LANL

To create industry standards, a precise mathematical model of perceived color space is needed. First attempts used Euclidean spaces which is the familiar geometry taught in many high schools. More advanced models used Riemannian geometry. The models plot red, green, and blue in the 3D space. Those are the colors registered most strongly by light-detecting cones on our retinas, and, not surprisingly, the colors that blend to create all the images on your RGB computer screen.

In the study, which blends psychology, biology, and mathematics, Bujack and her colleagues discovered that using Riemannian geometry overestimates the perception of large color differences. That's because people perceive a big difference in color to be less than the sum you would get if you added up small differences in color that lie between two widely separated shades.

Riemannian geometry cannot account for this effect.

"We didn't expect this, and we don't know the exact geometry of this new color space yet," Bujack said. "We might be able to think of it normally but with an added dampening or weighing function that pulls long distances in, making them shorter. But we can't prove it yet."

The work is funded through LDRD project 20200512ECR. Read the full article by Charles Poling here.

TOP SCIENCE IN THE NEWS

A Neutron in a Haystack

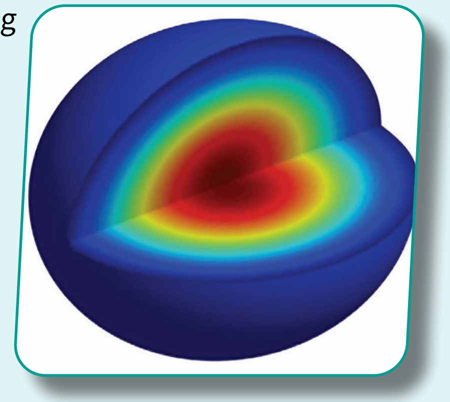
LANL Nuclear Physicist Anna Hayes devised a way to infer what's happening within the core of a nuclear-fusion experiment by observing a neutron everyone said would be unobservable

It's little wonder that nuclear fusion has long been one of humanity's great hopes to address the world's energy problems. Two isotopes of hydrogen fuse together and release millions of times more energy than an equivalent amount of fossil fuel. Indeed, just fifteen kilograms of fusion fuel provides about as much energy as 100,000 metric tons of coal. On top of that, it's carbon-free, and, unlike fission, its reaction products do not take the form of long-lived radioactive waste that must be stored. Apart from a spray of neutrons, which do not go beyond the reactor's containment structure, the only direct byproduct is helium, which is inert. All things considered, fusion power would be world-changing.

There are two primary ways to try to contain a multimillion-degree plasma (that is, a gas so hot that electrons detach from their atoms). One way is with a powerful magnetic field. The other way, used in inertial-confinement fusion (ICF), is a spherical implosion driven by lasers to compress the plasma, at least briefly. Unfortunately, in decades of experiments, the power required to maintain the magnetic field or drive the implosion has exceeded the power produced by the resulting fusion. Scientists have long been trying to achieve something we call "ignition": getting more power out than what we put in.

In the United States, there is a major ICF research facility that was built expressly for this purpose, the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in California. The scientists there work on ignition in earnest, with Los Alamos scientists helping collaborate with certain aspects of the problem, such as redesigning the fuel capsules or developing specialized instrumentation to see what's happening inside the imploding core.

Achieving ignition is difficult, but as Lawrence Livermore has recently proven, it is possible. While working towards ignition and wanting to better see what is happening inside, especially with neutrons, Hayes began to focus on reaction-in-flight (RIF) neutrons. RIF neutrons are part of a second, higher energy fusion reaction that occurs during compression when a fusion-borne, high-energy neutron from the core fusion region careens into a fuel ion outside the core, creating a one in ten thousand chance of a second reaction, or RIF neutron. Hayes devised a way to capture and measure the RIF neutrons, which then led to being able to directly connect RIF measurements to what was happening inside the exploding fuel capsule during fusion burn. Results indicate that RIF neutrons are able to provide indicators of conditions such as density, mixing, and pressure during NIF implosions that were unable to be determined by other means. This knowledge is proving useful in ongoing fusion research.



3D reconstruction of neutron-imaging data from a NIF fusion experiment. Image credit: LANL neutron imaging team.

The work has a long-term connection to LDRD project 20060081DR. Read the full article by Anna Hayes here.

TOP SCIENCE IN THE NEWS

Turtles Tell Tales

Turtle shells reveal a record of nuclear activity

Researchers at Los Alamos have a new way to study the presence of radioactive materials in the environment. The key to their research may seem unusual, but the scientists believe they have found the ideal recorder of nuclear events. It's a turtle.

Each unique layer of keratin (numbered) in an adult turtle's shell corresponds with one year of the animal's life. The layers can reveal which elements and isotopes were present in the turtle's environment when that layer was made. Photo credit: Derek Hall, Nevada National Security Site.

As a turtle or tortoise grows, each year its shell produces a thin layer of keratin that then becomes inert. Layers build up, like rings of a tree, and elements from the environment are trapped within the layers. In this way, the shell maintains a time-constrained record of all the environmental conditions in which the animal lived.

Among various kinds of environmental signatures, turtle shells can pick up very small concentrations of radionuclides. These are radioactive forms of elements, some of which form naturally while others are formed anthropogenically. Project lead Cyler Conrad and his team are looking specifically at anthropogenic uranium, plutonium, strontium, and others.

Turtle shells are excellent recorders of the pollutants in their environment because the elements are locked in the inert keratin layer in which they were first deposited. Two advantages of using turtles and tortoises for the study is that they can be found just about everywhere, and they have long lives.

The team began by using shells of deceased turtles from museums and other natural-history collections. A clear record of anthropogenic uranium contamination was found with a sample from a box turtle collected in 1962 from Oak Ridge, Tennessee, home to Oak Ridge National Laboratory, which has been a major center of nuclear energy research since 1942.

Now that the Los Alamos team has proven that the approach works with archival samples, the next step is to collect live samples including box turtles from around the Trinity Site, desert tortoises from the Nevada National Security Site, and sea turtles from the Marshall Islands. The process does not hurt the animals and is comparable to people cutting their fingernails.

The research will identify patterns of radiation exposure and examine the long-term impact of low-level radiation exposure over time on organisms and ecosystems.

The work is funded through LDRD project 20210220ER. Read the full article by Jill Gibson here.

LDRD IMPACT STORY

Los Alamos National Laboratory LDRD Investments in Plutonium Excellence

As the Nation's R&D Plutonium Center of Excellence, Los Alamos is involved in the design of next-generation plutonium processing. LDRD supports this priority through project investment. Below are highlights from a few of the many project investments LDRD has made over time in promoting Los Alamos' plutonium (Pu) excellence.

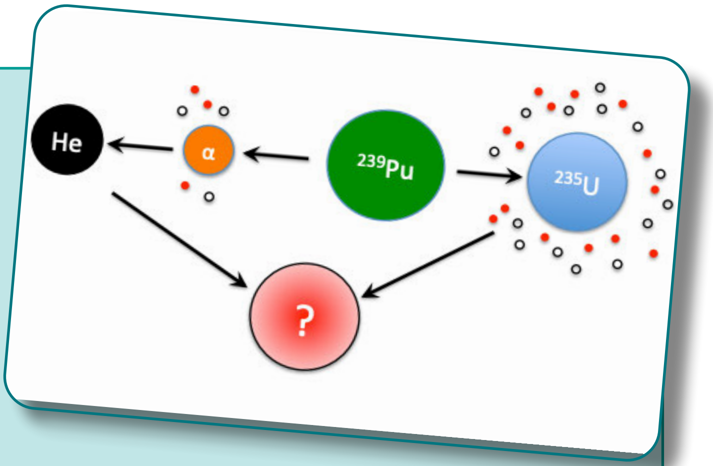
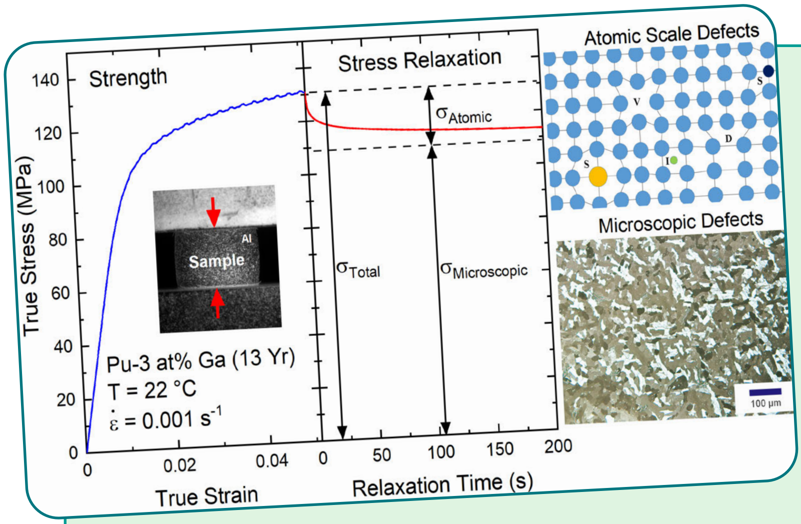


Image of a plutonium decay event.
Image credit: LANL

Aging in Delta Plutonium Alloys: A Fundamental Approach

Project: 2010057DR
PI: Franz Freibert

The project worked to quantify and understand the radiogenic changes in delta-Pu induced by helium ingrowth, defect accumulation and delta-Pu phase instability as determined by consensus of state-of-the-art experimental, computational and modeling tools. The project resulted in numerous unprecedented, groundbreaking experimental and theoretical findings and received follow-on funding for continued research support.



Plutonium Defect Characterization through Mechanical Deformation

Project: 20200557ER
PI: Taylor Jacobs

This project sought to introduce stress relaxation and internal friction experiments to plutonium metallurgy.

The project was able to successfully implement stress relaxation in order to study defects that were related to both aging and processing. The work proved that aging and processing related defect evolution can be characterized using mechanical deformation and let to follow-on funding.

Above: The stress relaxation technique is a mechanical test designed to separate the contributions of atomic scale and microscopic defects to the total strength of the material. Image credit: LANL

Design for Manufacture Pit Feasibility Study

Project: 20200665DI
PI: Christina Scovel

The project focused on the development of one or more prototype pits that would be able to demonstrate Design for Manufacture (DfM) improvements, as well as develop an integrated certification and qualification plan for the example DfM pit.

The project concluded successfully and has received follow-on funding.

This project focused on the development of a prototype pit at Los Alamos. Photo credit: LANL

Ultra-High Resolution Gamma Spectroscopy for Plutonium Facility Materials Characterization

Project: 20220628DI
PI: Mark Croce

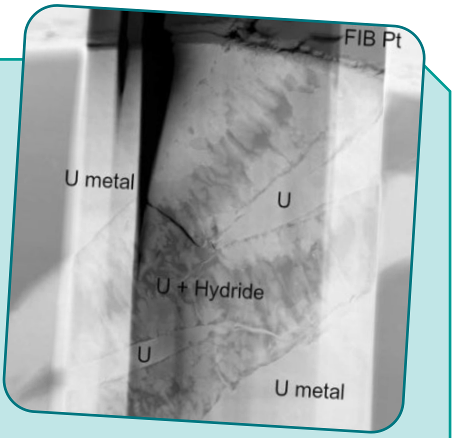
Ultra-high resolution microcalorimeter gamma spectroscopy (UHRGS) is a fundamentally new rapid, nondestructive isotopic analysis technology that provides a path to greatly reduce measurement delays in the Los Alamos National Laboratory Plutonium facility. Continued data from the project will be used for precise determination of information needed in plutonium and americium isotopic analysis.

Above: Prototype instrument pictured used to develop a next-generation rapid and nondestructive nuclear material accounting measurement technique to improve the efficiency of operations at the Nation’s only Plutonium Facility. Photo credit: LANL

Understanding Plutonium Corrosion on Machined Surfaces

Project: 20230202DR
PI: Sarah Hernandez

The work in this project will inform plutonium production and manufacturing for Los Alamos National Laboratory. This project will produce a series of targeted experimental results that will inform the development of a predictive two-dimensional kinetic model for reactions. The project will address long-standing questions and hypotheses concerning the location and reactivity of hydride nucleation sites, by integrating microstructure and corrosion data.



A suite of experimental techniques will be used to understand the plutonium hydriding problem from different aspects. Image credit: LANL

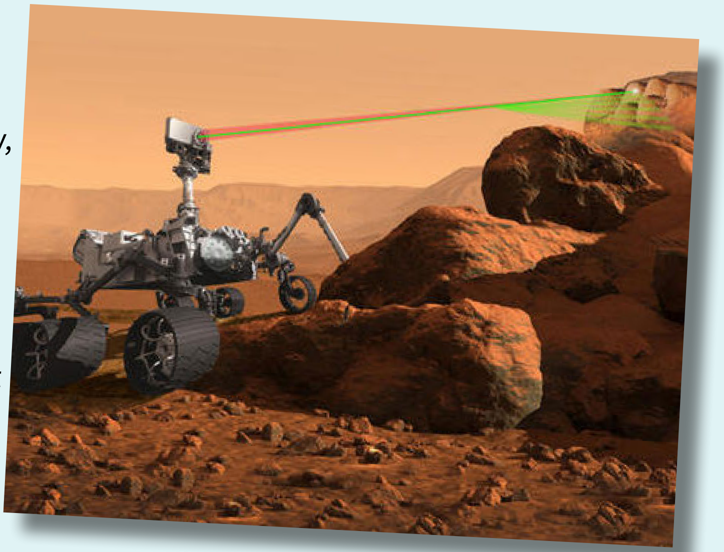
LDRD IMPACT STORY

Los Alamos National Laboratory LDRD Investments in MARS Rover Technology

Scientists on NASA's Perseverance mission made a surprising discovery about the composition of rock in Jezero Crater. The new research shows that Jezero Crater is largely made up of igneous rock, rather than sedimentary rock.

The crater where Perseverance landed in 2021 held water billions of years ago. For that reason, scientists predicted that rock in the area would be sedimentary, formed over time from settled mud, which would be the case for lakebeds on Earth. But to their surprise, they found that rock in Jezero is igneous, which is formed by volcanic magma.

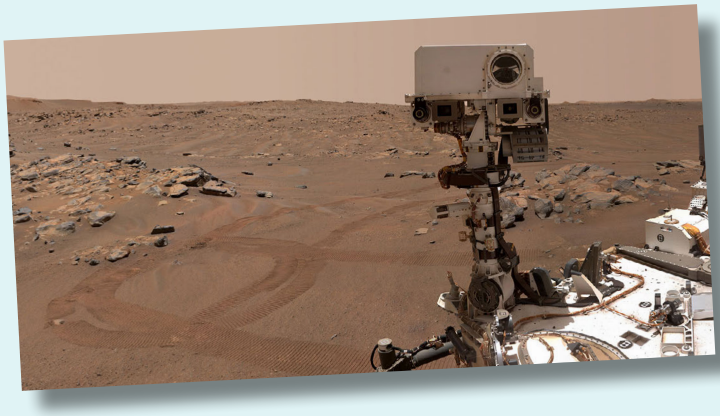
"Finding these igneous rocks in the bed of an ancient lake on Mars was quite a surprise. One would have expected lakebed sediments, but it shows that Mars' history is more complicated than expected, including lava flows in this ancient site," said Roger Wiens, PI on the SuperCam instrument, in a recent article.



Artist rendering of the SuperCam instrument aboard the Mars Perseverance. Image credit: NASA

On September 2nd of 2022, the SuperCam instrument was even able to detect frost on Mars using a combination of Mars Environmental Dynamics Analyzer (MEDA) and SuperCam instruments.

The science that led to this work did not start with the Perseverance and the SuperCam. LDRD funding of scientific and instrumentation research for Mars rover technology began more than a decade ago. In 2006, LDRD funded an Exploratory Research project led by Roger Wiens that focused on further development of a laser-based method of prospecting or determining compositions remotely. The technique is called Laser Induced Breakdown Spectroscopy or LIBS and is used to determine elemental compositions of samples at some distance (up to seven meters on Mars) with no sample preparation. Laser pulses focused on the target produce plasma "sparks" composed of material ablated from the target. Each element present in the sample produces light at discrete wavelengths. By measuring the optical spectrum of the emitted light (the color) from the sparks, the elemental composition can be determined.



Selfie from NASA's Perseverance Mars rover. Photo credit: NASA/JPL-Caltech/MSSS.

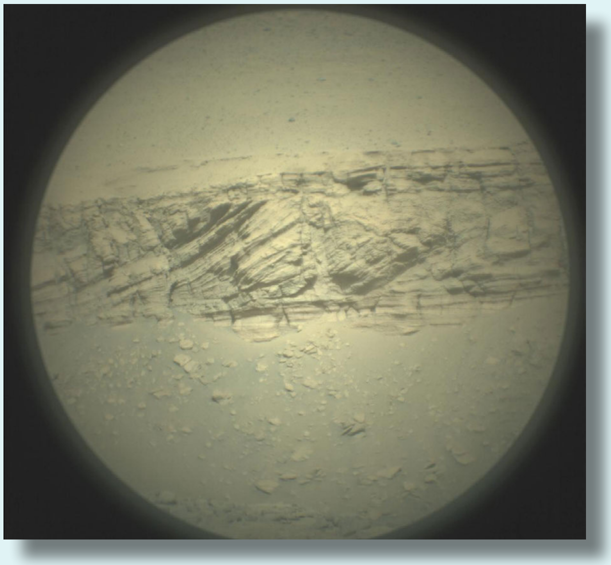
At that time, LIBS had been selected for use on the Mars Curiosity rover. The intent of the project was to improve the accuracy and precision of the LIBS technique while also developing a better understanding of how LIBS would perform in an airless environment. The work of the *20061502ER Laser Induced Breakdown Spectroscopy* project developed into an Exploratory Research project, *20080718ER, Accuracy of Laser-Induced Breakdown Spectroscopy*, also led by Roger Wiens. The new project looked at all wavelengths for each element rather than single wavelengths as had been done in the past. With accuracy and detection limits significantly improved, the next step was to combine LIBS with Raman spectroscopy.

Raman spectroscopy is fundamentally sensitive to molecular structure while LIBS primarily determines elemental compositions. A 2010 Exploratory Research project, *20100230ER, Planetary Analog Geochemical Explorations with Laser-Induced Breakdown and Raman Spectroscopies*, led by Roger Wiens and Samuel Clegg, combined LIBS-Raman analysis of planetary analog samples to develop a new understanding of surface chemistry and mineralogy of lunar samples and small-scale analyses of carbon-rich asteroidal materials. The success of ChemCam on the Mars Curiosity rover also caught the attention of others in the planetary science community. Parts of the Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument led by NASA's Jet Propulsion Laboratory (JPL) were derived from the ChemCam spectrometers and developed at LANL under the leadership of Tony Nelson, a scientist with LANL's Intelligence and Space Research Division. Samuel Clegg and Roger Wiens are both members of the SHERLOC science team.

Mars Curiosity with CHEMCam. Photo credit: Reuters/NASA/JPL

The achievements made with the ChemCam instrument also helped inform a 2013 Exploratory Research project led by Samuel Clegg, *20130801ER, Remote Raman-LIBS Spectroscopy: Preliminary Tests for the Next Mars Rover*. The project worked to demonstrate that a frequency doubled ChemCam laser could be used to produce Raman spectra. The project work was to collect Raman and LIBS spectra from up to 20 geochemical standards containing a complex mineralogical mixture. A quantitative molecular composition would be extracted from the Raman spectra while the quantitative elemental composition would be extracted from the LIBS spectra.

The successful execution of LDRD project *20140033DR, Remote Raman-LIBS Spectroscopy (RLS) Signature Integration,* led by Samuel Clegg was critical to the selection of the SuperCam instrument on the Perseverance rover. Part of this DR project developed the first prototype miniature transmission spectrometer that enabled the collection of the weak Raman spectrum and part of the bright LIBS spectrum. A modified version of this prototype transmission spectrometer is now operating on SuperCam and is also capable of recording Time-Resolved Luminescence Spectra and Passive Visible and Near Infrared Spectra.



NASA's Mars Perseverance rover acquired this image using the SuperCam Remote Micro-Imager. Image credit: NASA/JPL-Caltech/LANL/CNES/IRAP

Research from the 2014 LDRD project and these more recent LDRD projects:

- *20180244ER, OrganiCam: A High-Sensitivity Radiation-Hardened Imaging Organic Detector for Space and Programmatic Applications*, led by Roger Wiens,
- *20190628ER, Using Acoustic Signals from Laser-Induced Breakdown Spectroscopy Plasma Shock Waves to Identify Surface Coatings and Layers on Martian Rocks*, led by Nina Lanza,
- *20190238ER, Boron and Ribose in Clay: A Precursor for Life on Earth and Mars?*, led by Patrick Gasda, and
- *20210424ER, Listening for Rock Coatings on Mars: Using Acoustic Signals from Laser-Induced Breakdown Spectroscopy,*led by Nina Lanza,

are now providing us with the current discovery information of igneous rock from the Jemez Crater floor and the detection of frost on Mars.

The initial LANL LDRD R&D investments into LIBS were critical to the selection of the ChemCam instrument that has collected LIBS spectra from over 900,000 laser shots on Mars as well as the selection of the SHERLOC instrument operating on the Perseverance rover. Subsequent LDRD scientific and engineering investments enabled the integration of Raman and LIBS in a single instrument and the selection of the SuperCam instrument on the Perseverance rover. Finally, these LDRD and NASA projects have also resulted in many more DOE programs led by many additional members of these project teams.

Project Summaries

The remainder of this report provides project summary information on all LDRD projects funded in FY22. The project summaries are organized by Capability Pillar – Complex Natural and Engineered Systems, Information Science and Technology, Materials for the Future, Nuclear and Particle Futures, Science of Signatures, and Weapons Systems. Project summaries for continuing projects appear first, followed by project summaries and technical outcomes for projects that ended in FY22.
All images included with the project summaries are credited to Los Alamos National Laboratory unless otherwise noted.

The project summaries are compiled in a stand-alone document and are available by clicking the link below.

LDRD FY22 Compendium of Project Summaries

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