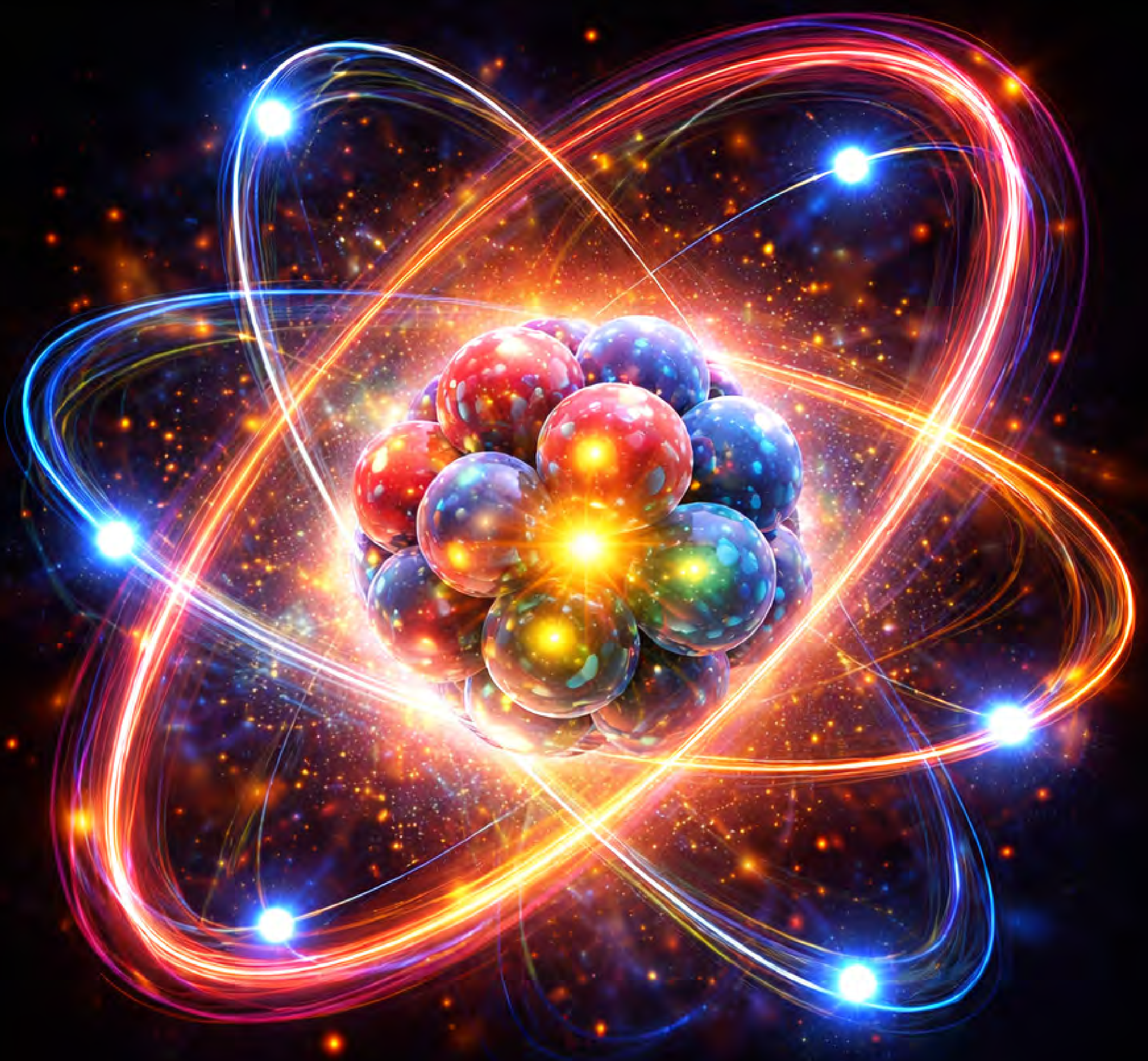
FY25 Annual Progress Report

Laboratory Directed Research and Development Program

Los Alamos National Laboratory



Los Alamos NATIONAL LABORATORY

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT WHERE INNOVATION BEGINS

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LABORATORY DIRECTED RESEARCH & DEVELOPMENT

FY25 Annual Report

Structure of this Report
The Laboratory Directed Research and Development (LDRD) Annual Report for fiscal year 2025 (FY25) 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.

The Annual Report is available at:
https://www.lanl.gov/engage/organizations/nnsa-directed-r-and-d/annual-reports

On the Cover
Cover Image: This image was created using advanced generative AI tools (ChatGPT).

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

ChatGPT and Microsoft 365 Copilot Chat were used as supportive tools in the development of this report to enhance clarity, refine grammar, and generate visual elements.

LA-UR-26-22513

Leadership Perspectives

KIRSTEN MCCABE
LDRD PROGRAM DIRECTOR

I am honored to have joined the LDRD program as the Program Director this past July. As I reflect on my time in this new role, I am inspired by the program's strength and vitality and energized by the opportunities ahead. LDRD represents the Laboratory at its most forward-looking; investing in bold ideas, empowering creativity, and positioning our institution to lead in emerging scientific and technological frontiers. From day one, I have been impressed by the program's culture of innovation and accountability, enabling agile solutions to emerging scientific and national security challenges.

One of the program's greatest strengths is its people. The dedication and professionalism of the LDRD staff are exceptional. The team brings not only technical expertise and institutional knowledge, but also a clear commitment to service and transparency. I have been particularly struck by how thoughtfully the staff supports project staff and reviewers alike, ensuring that the program operates with integrity while remaining accessible and responsive. That foundation of trust and competence is a tremendous asset.

During the final quarter of the fiscal year, we introduced targeted enhancements designed to further strengthen the program. These include expanding leadership and mentorship opportunities to further strengthen the innovation pipeline, improving communication touchpoints with project teams to support and accelerate transition planning, and increasing program agility through new rolling proposal calls with short-cycle tracks. These changes reflect the our continued commitment to program improvement, ensuring LDRD remains agile, transparent, and aligned with Laboratory priorities.

Looking ahead, I am excited about the opportunities before us. LDRD plays a critical role in shaping the Laboratory's future capabilities, seeding innovation, and developing the next generation of scientific leaders. I am grateful for the warm welcome I have received and deeply appreciative of the expertise and partnership across the community. Together, we will continue to strengthen this already outstanding program and ensure it remains a cornerstone of our mission success.

Leadership Perspectives

JACOB WALTZ
LDRD DEPUTY PROGRAM DIRECTOR

The LDRD Program remains one of the Laboratory's most significant and impactful investments, and I am continually impressed by the quality and breadth of groundbreaking research it enables each year. From advances in artificial intelligence and quantum computing to modernization of technologies, the program's portfolio exemplifies technical excellence and a forward-looking vision, positioning the Laboratory to address emerging challenges with agility and creativity.

Over the past year, we've seen a significant increase in proposal submissions across many of our proposal calls, clear evidence of strong engagement and enthusiasm within the research community. This growing interest emphasizes LDRD's role as a catalyst for bold ideas and high-impact science. As demand for the program expands, LDRD remains committed to upholding the rigor, fairness, and transparency that define our review process, while advancing new initiatives to strengthen and streamline operations. Through thoughtful implementation of these improvements, we aim to meet the evolving needs of the Laboratory while safeguarding the integrity of the program.

LDRD remains a powerful vehicle for attracting and developing exceptional talent. By funding cutting-edge research opportunities, the program helps bring promising new staff to the Laboratory and empowers early-career researchers to pursue creative, high-risk ideas. In FY25, 63% of the Postdoctoral Researchers at the Laboratory were supported by LDRD. The energy and creative ideas these researchers contribute are significant assets—not only to LDRD, but to the long-term vitality of the Laboratory itself.

This year's Annual Report highlights the exciting research supported through LDRD, including program milestones, impact stories, and the many accomplishments of our talented research and development staff. I am proud of the work enabled by this program.

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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 (ST&E). 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.

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. 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. This in turn helps the Laboratory, and the Nation, maintain its position of scientific and technological leadership.

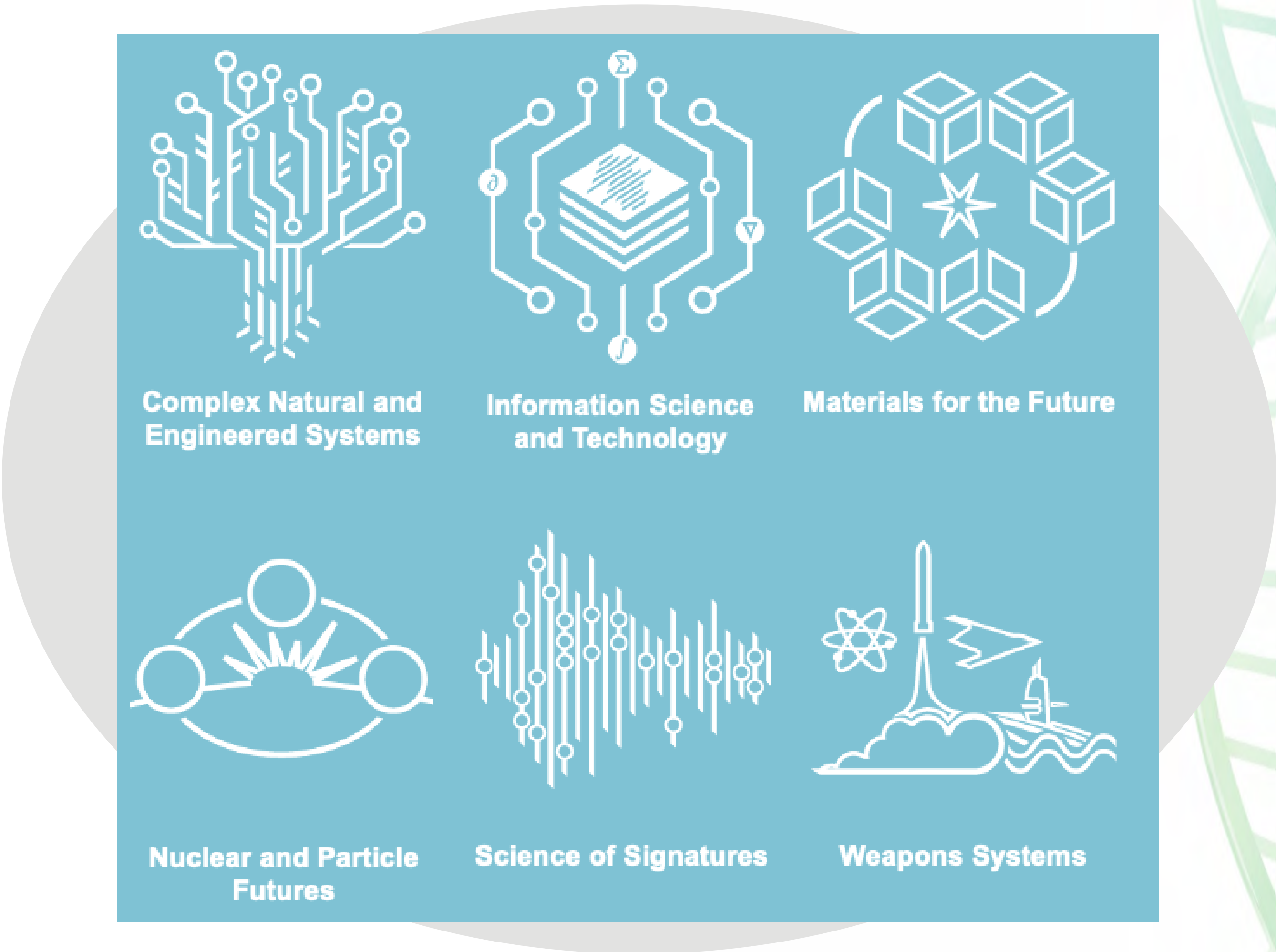
LDRD objectives guide the overall program and align with DOE Order 413.2C Chg1. The LDRD program has three objectives: Technical Vitality, Mission Agility, and Workforce Development.

The LDRD program responds to four national security challenges. 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 weapons of mass destruction threats.*
3. *Deter and defend against threats in multiple domains.*
4. *Strengthen our energy and environmental national security.*

CAPABILITY PILLAR INVESTMENT

LDRD supports Laboratory strategy through our alignment with the Laboratory's Capability Pillars. These six Pillars define strategic investment areas at Los Alamos for present and future missions. All LDRD investments support one or more Capability Pillars.



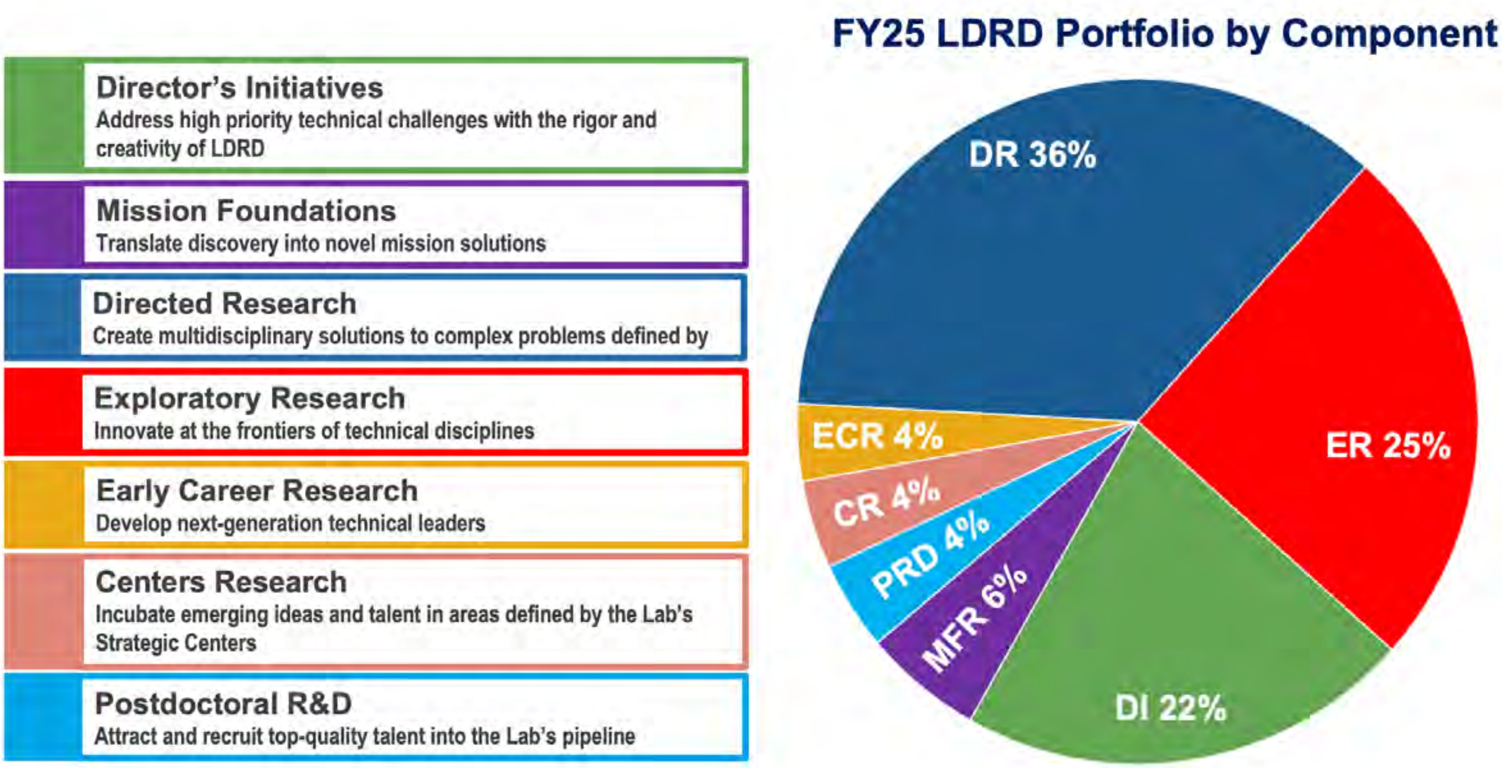
Program Structure

OVERVIEW

The Los Alamos LDRD program is organized into research components that each have distinct institutional objectives. The amount of investment in each component is intentionally planned to balance the overall LDRD portfolio.

In FY25, the LDRD program allocated $230M to 442 projects that incurred total costs of $227M. These projects were selected through rigorous and highly competitive peer review processes and are reviewed formally and informally throughout the fiscal year.

The graphic below shows the percentage of the total FY25 LDRD budget invested in each component.



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

In FY25, LDRD funded 19 Director's Initiative (DI) projects, investing $49M which represents 22% of the program's research funds.

LDRD DI projects are targeted efforts that focus on Strategic Lab priorities and near-term opportunities. Project length varies, with each project typically running 1-2 years in length.

Proposed projects are championed by Senior Laboratory leaders who work with the LDRD Program Office, the Deputy Director for Science, Technology and Engineering (DDSTE), and the Deputy Director for Weapons (DDW) to identify projects and PIs. Once identified, the LDRD Program Office invites proposals and subjects them to a full peer review process. Proposals are held to the same standards of excellence as all other LDRD proposals and undergo a non-competitive technical peer review to assess support of LDRD objectives and soundness of research approach.

Director's Initiative Research in Action

This DI project will test and evaluate artificial intelligence (AI) capabilities across LANL mission areas while assessing risks in high-consequence applications such as materials, biosecurity, energy, and multi-physics. Leveraging LANL's unique scientific expertise, data assets, and high-performance computing, it will address challenges in data management and computational scaling to optimize AI integration. The outcome will be an agile pipeline for testing, risk assessment, and deployment that positions LANL as a leader in AI evaluation and mission-critical applications.

The project will develop, test, and evaluate the capability to assess the performance of AI methods. Image by ChatGPT.

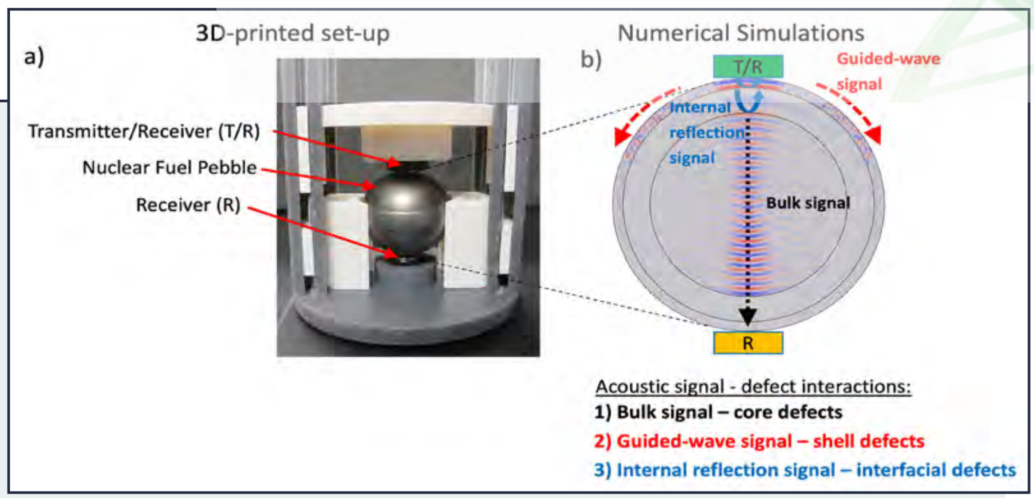
PI: Earl Lawrence
LDRD Project: 20250639DI Artificial Intelligence for Mission: Test, Evaluation, and Risk

MISSION FOUNDATIONS RESEARCH: TRANSLATE DISCOVERY INTO NOVEL MISSION SOLUTIONS

In FY25, LDRD funded 24 Mission Foundations Research (MFR) projects, investing $12.8M which represents 6% of the program's research funds.

MFR addresses mission need in the technology readiness level (TRL) 3-6 regime. Proposals must respond to mission problem statements reflective of mission needs across the Laboratory.

There are two project phases within the MFR component. Staff propose solutions to MFR problem statements in an initial competition (Phase 1), and teams that are 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 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 downselect competition. Phase 1 and Phase 2 projects are each 12 months in length.



The project's new NDE technique involves the use of high-resolution acoustic signals to detect defects in advanced nuclear fuel pebbles, where a) transmit/receive (T/R) and receive (R) sensors are used in a 3D-printed fixture, b) allowing utilization of bulk, guided, and internally reflected waves for various wave-defect interactions.

Mission Foundations Research in Action

Next-generation nuclear fuels use graphite pebble architectures to handle the higher operating temperatures of emerging advanced nuclear reactors. Accurate and rapid inspection of these nuclear fuels for defects and damage will be crucial during their manufacturing and use. However, there is currently no rapid, scalable technology to assess the quality of these pebbles.

This project aims to develop an acoustic non-destructive evaluation (NDE) method that can detect most relevant defects/damage in these structures with high accuracy and speed. The novel acoustic NDE capability that will be developed will not only support research activities in rapid, non-invasive diagnostics of experimental fuel fabrication processes, but also in future real-time monitoring of fabrication processes in industrial settings.

PI: Alp Findikoglu
LDRD Project: 20250658MFR Rapid Acoustic Inspection of Advanced Nuclear Fuels

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

In FY25, LDRD funded 46 Directed Research (DR) projects, investing $81M, which represents 36% of the program's research funds.

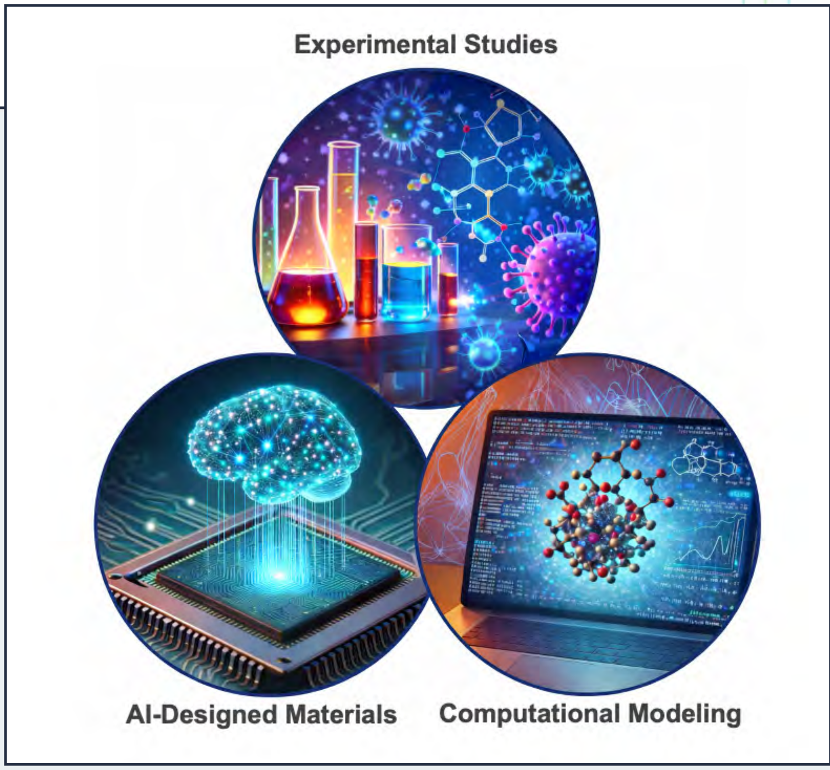
DR projects are aligned to key competency or technology-development areas vital to LDRD's long-term ability to enable the Lab to execute its missions. Funding for individual DR projects is approximately $2M per year for three years.

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. Laboratory leadership provides strategic guidance to SIP Development Teams associated with each Pillar. The teams then engage with Laboratory staff to identify investment priorities for the upcoming fiscal year that are consistent with and supportive of the long-term Pillar strategy. Priorities may include not just strategic capabilities, but also mission challenges requiring new and innovative approaches.

Directed Research in Action

Traditional explosive discovery relied on slow, iterative modifications to known materials that often led to new explosives that perform no better than current materials.

This project will bring explosive discovery into the modern age by using generative artificial intelligence (AI). The project develop an AI framework with desired metrics, such as explosive performance and stability towards heat, and the generative AI will produce new explosive structures as synthetic targets. Once synthesized, these new explosives will be subjected to experimental testing to validate their performance and thermal stability.



The design and synthesis of new heat-resistant explosives will occur through an iterative approach, where experiment will guide computational modeling, which will be used to develop a database of material properties to train an artificial intelligence algorithm. Artificial intelligence will be used to predict new materials, which will be validated experimentally through synthesis, thermal analysis, and performance.

PI: Christopher Snyder
LDRD project: 20250006DR, Accelerated Discovery of Heat-Resistant Explosives

EXPLORATORY RESEARCH: INNOVATE AT THE FRONTIERS OF TECHNICAL DISCIPLINES

In FY25, LDRD funded 193 Exploratory Research (ER) projects, investing $57M which represents 25% of the program's research funds.

The ER component is the most important channel for purely bottom-up creativity at the Laboratory. Initiated by technical staff from across the Laboratory, ER projects explore highly innovative ideas in 10 Technical Categories that underpin Laboratory missions. Funding for individual ER projects is approximately $350K per year for three years.

Exploratory Research also funds ER Seedlings and ER Interlaboratory projects. 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. Interlaboratory projects are funded for two and a half years and offer a structured and supported path for multi-Laboratory collaborations on key shared national strategic goals. Funding levels vary for Interlaboratory projects.

Exploratory Research in Action

Accelerated aging studies are a crucial aspect of developing new materials for mission-relevant applications. They represent a problematic step in the process since over-acceleration of the aging can drive the system into a different response regime, changing the fundamental physics and chemistry of the aging process.

This project will develop a protocol tool based on nonequilibrium phase transitions that eliminates the guesswork in accelerated aging studies and allow experimenters to produce accurate accelerated aging results that remain in the same regime as ordinary aging.

PI: Cynthia Reichhardt
LDRD Project: 20250118ER Accurate Predictions from Accelerated Corrosion Aging Across Nonequilibrium Phase Transitions

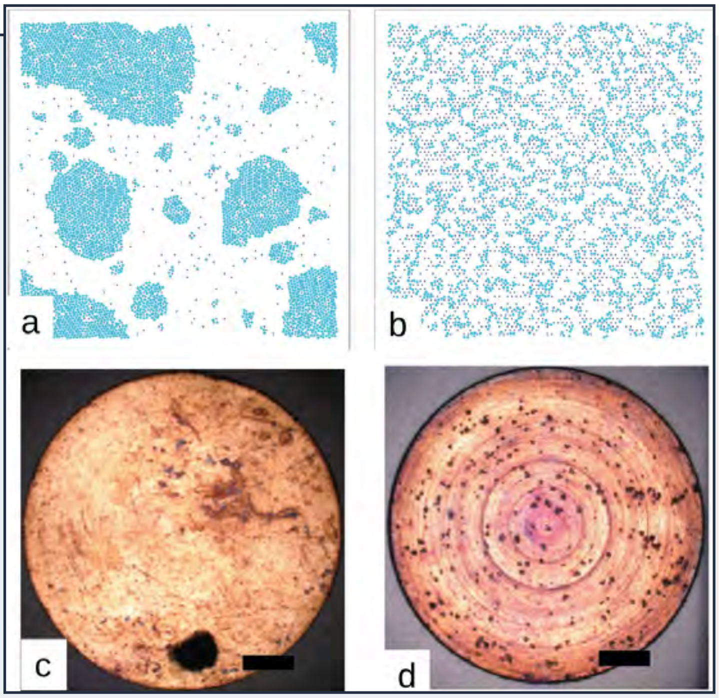
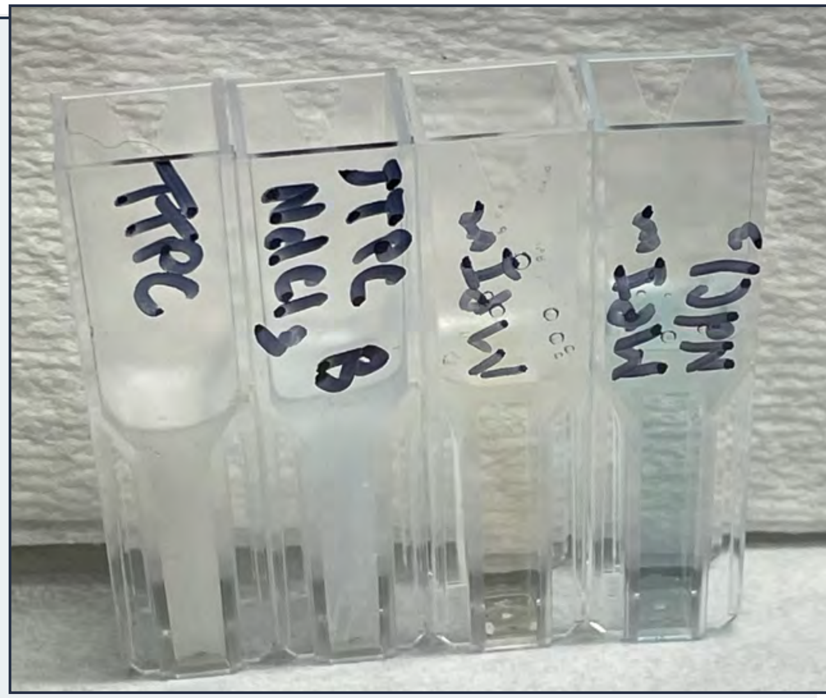


Image: (a,b) show simulations of two corrosion morphologies: (a) a small number of large spots and (b) a large number of small spots. (c,d) show the corresponding morphologies observed in uranium hydride coupon experiments performed.

Exploratory Research Seedlings in Action

Detectors used to measure and track radioactive materials require annual calibration, but the current calibration standards have a usable life of less than one week. This difficult calibration process limits the use of these detectors and prevents their use for measuring other radioactive materials needed for energy programs.

This project proposes using special room temperature ionic liquids instead of acid-based solutions, as these liquids don't evaporate easily and resist damage from radiation and heat. These liquids are thick or even solid at room temperature, which prevent leaking and contamination while extending the usable life of the calibration standards.



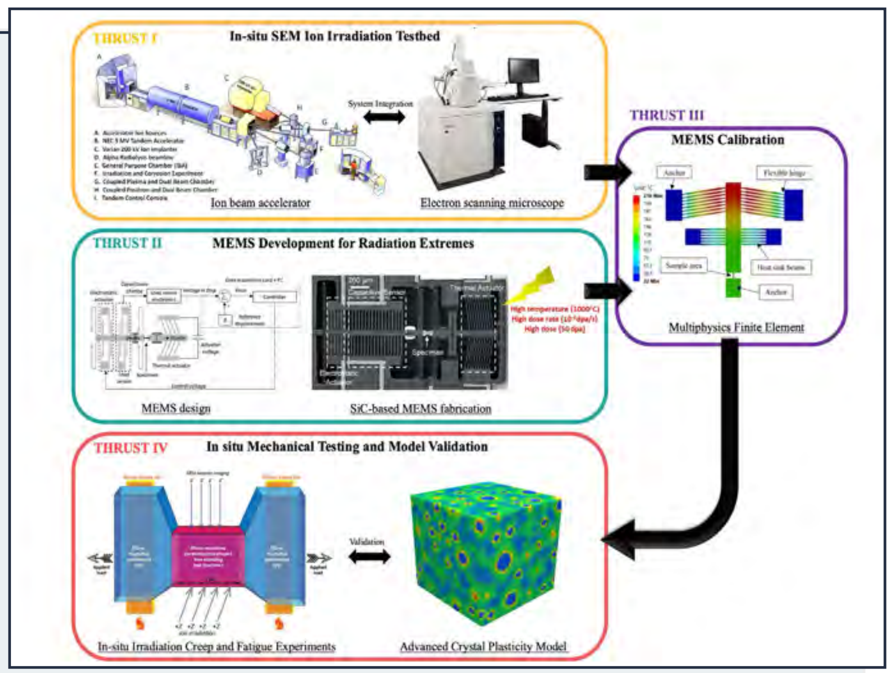
Sample containers showing (from right to left) two different types of ionic liquids, both with and without dissolved neodymium, after seven months of storage.

PI: Cassara Higgins
LDRD Project: 20250935ER Room Temperature Ionic Liquids as a Solid Matrix for Modernization Plutonium Solution Assay Instrumentation Standards

Interlaboratory Research in Action

This collaborative, multi-lab project involving Los Alamos, Idaho, and Sandia National Laboratories will stand up a novel in situ ion irradiation testbed and microelectronic mechanical system based mechanical devices to enable real time irradiation creep and fatigue measurements of novel structural nuclear materials.

Using this capability in conjunction with advanced modeling and simulation tools, the team will demonstrate that in situ small-scale mechanical measurements can be used to provide representative data that enables one to predict the in-reactor creep performance of candidate nuclear materials.



Outline of the four thrusts and their activities for developing in-situ irradiation creep and fatigue testing.

LANL PI: Hi Vo
INL PI: Ryan Sweet
Sandia PI: John Nogan
Project: 20250863IL Accelerated Qualification of Novel Nuclear Structural Materials: Assessing Irradiation Creep and Irradiation Thermal Fatigue Properties Through In Situ Testing and Multiphysics Simulations

EARLY CAREER RESEARCH: DEVELOP NEXT-GENERATION TECHNICAL LEADERS

In FY25, LDRD funded 51 Early Career Research (ECR) projects, investing $8.2M, which represents 4% of the program's research funds.

Targeted research opportunities for early career (EC) staff are essential to building the Laboratory's future scientific workforce. LDRD's EC-focused projects help bridge the transition from postdoctoral or student roles to full-time staff positions while advancing research in disciplines aligned with the program. Eligible PIs must have earned their highest degree within the past ten years and joined the Laboratory as technical staff no more than three years prior to the call.

In the final quarter of FY25, LDRD introduced a key program enhancement: EC leadership opportunities will now be embedded within the ER call starting in FY26, replacing the previous standalone ECR component. This integration expands opportunities for EC staff to lead larger projects while ensuring these projects remain a priority by allowing researchers to identify as EC during proposal submission. LDRD has set a goal for approximately 10–20% of funded proposals to be led by early career researchers, underscoring our commitment to developing future scientific leaders. Each project is funded up to $240K per year for two years.

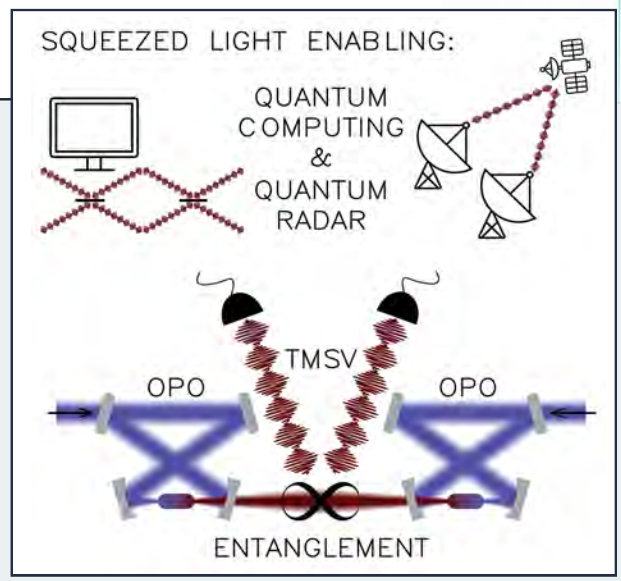
Each project is funded up to $240K per year for two years, providing critical support during this formative stage.

Early Career Research in Action

Computing and remote sensing are two areas that are significant to LANL missions, which would benefit from quicker, more powerful computing and from long-range sensing with lower noise and higher resolution and accuracy.

This project will improve upon both computing and sensing concurrently by creating two-mode squeezed vacuum (TMSV) states, for use in quantum computing and advanced sensing applications such as quantum radar.

PI: Kristina Meier
LDRD Project: 20240609ECR Entanglement of Two Single-Mode Squeezed States for Measurement-Based Quantum Computing and Quantum Sensing Applications

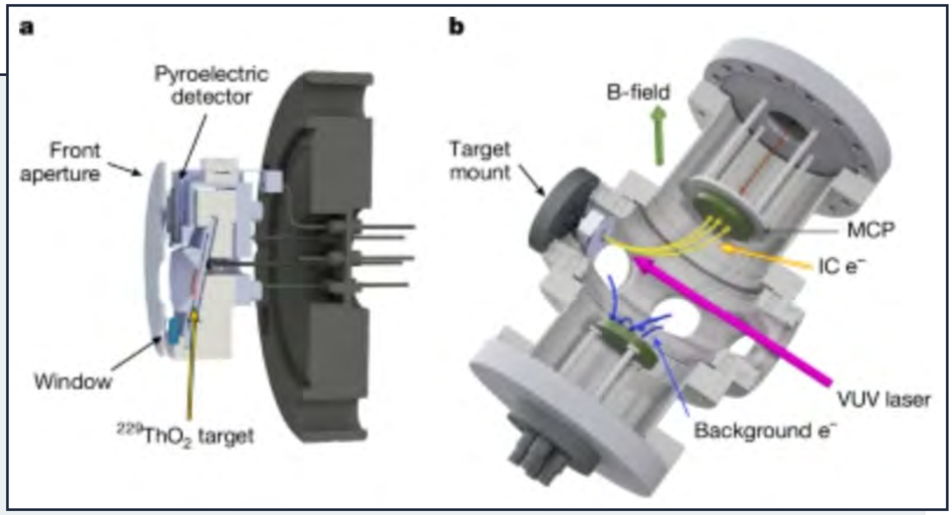


Squeezed light reduces noise beyond classical limits, enabling advanced quantum applications. Two-mode squeezed vacuum (TMSV) states—created by pumping two optical parametric oscillators (OPOs) with a powerful laser and entangling their outputs—are critical for photonic quantum computing and improving radar sensitivity. The quality of squeezed light is measured by its noise reduction compared to un-squeezed light.

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

In FY25, LDRD funded 7 Centers Research (CR) projects, investing $9.4M, which represents 4% of the program's research funds.

LDRD has a strong history of partnership with the Lab's "Strategic Centers." This partnership provides opportunities to develop the Nation's next-generation workforce and leadership talent and serves 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.



Cutaway rendering of the 229ThO2 target mount (a) and rendering of the spectroscopy chamber (b). Credit: LANL

Centers Research in Action

The exceptionally low-energy 229Th nuclear isomer could enable nuclear clocks, tests of fundamental physics, superradiance, and laser Mössbauer–based sensing in solids, but current approaches are constrained by the need for high-bandgap, VUV-transparent host materials. In a recently published article, LANL researchers Daniel Rehn and Bao Tran Tan report the first (to the authors' knowledge) demonstration of laser-induced conversion electron Mössbauer spectroscopy (CEMS) of the 229Th isomer in a thin ThO2 sample whose bandgap (approximately 6 eV) is considerably smaller than the nuclear isomeric state energy (8.4 eV). Unlike fluorescence spectroscopy of the 229Th isomeric transition, this technique is compatible with materials whose bandgap is less than the nuclear transition energy, opening a wider class of systems to study and the potential of a conversion-electron-based nuclear clock.

This work was supported by LDRD Center's project 20250613CR-IMS, Nucleating Materials Research and Development, led by Filip Ronning; and LDRD project 20260021DR, Nuclear Clocks for Deterrence, led by Daniel Rehn and Michael Martin.

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

In FY25, LDRD funded 102 Postdoctoral Research and Development (PRD) projects, investing $9.6M, which represents 4% of the program's research funds.

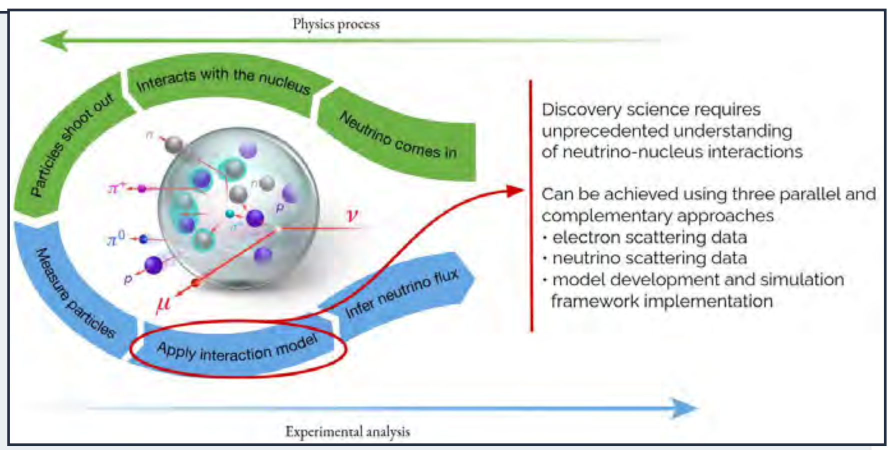
The PRD component of the LDRD program ensures the vitality of the Laboratory by recruiting early career researchers. Through this component, LDRD funds Postdoctoral Fellows to work under the mentorship of PIs on highly innovative projects. Postdoctoral projects are individually funded up to $200K per year for 2-3 years. The review and selection processes are conducted by the Los Alamos National Laboratory Postdoc Program Office.

PRD projects are funded under two appointment types:

- Director's Postdoctoral Fellows - Funding for this appointment type follows a stepped approach: 100% (year 1), 66% (year 2), and 33% (year 3, if the project is extended for a third year). The intent is to encourage the Fellow to engage in programmatic work as their postdoctoral appointment progresses. This familiarity often leads to long-term Lab career opportunities.
- Distinguished Postdoctoral Fellows- These PRD Fellows receive full-time support at a highly competitive salary for three years. Full-time support allows the Distinguished Fellows considerable freedom to pursue their own ideas.

Postdoctoral Research in Action

The Standard Model (SM) of Particle Physics has been established as the theory governing the building blocks of our universe. Nevertheless, astronomical evidence of dark matter, neutrino oscillations, and the muon anomalous magnetic moment are hints that the SM is not the ultimate theory. To address these shortcomings, the elusive particles called neutrinos are used to investigate experimental observations.



Flow chart shows this complex process that involves differentiating the physical neutrino interactions (green) from the experimental analysis (blue) to extract the true neutrino energy spectrum.

The primary focus of this project lies on confronting the currently-insufficient neutrino-nucleus modeling precision. This insufficiency threatens to limit the sensitivity of flagship neutrino experiments, where there is a critical need to reduce the current systematic uncertainties. The team will leverage their unique expertise in analyzing electron and neutrino scattering data, cross-section extraction and neutrino event generator modeling, in order to make fundamental and critical improvements to our understanding of neutrino-nucleus interactions.

PI: Sowjanya Gollapinni
Postdoctoral Researcher: Afroditi Papadopoulou
LDRD project: 20251150PRD1 Unraveling the Nature of Neutrino Interactions

Program Value

LDRD supports high-risk, potentially high-payoff research and development, serving as a key resource for addressing the ST&E goals of the Laboratory. 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 metrics shared on the following pages demonstrate how the LDRD program at Los Alamos successfully addresses the LDRD program objectives of Technical Vitality, Mission Agility, and Workforce Development.

FY25 KEY PERFORMANCE INDICATORS

$227M
Total Program Cost

442
Total Number of LDRD Projects

149
New LDRD Projects in 2025

29%
9 of 31 U.S. patents issued at LANL can be attributed to LDRD

40%
40 of 101 invention disclosures issued at LANL can be attributed to LDRD

46%
86 of 187 software copyrights at LANL can be attributed to LDRD

100%
3 of 3 R&D 100 Awards at LANL can be attributed to LDRD

38%
830 of 2,157 unclassified publications at LANL can be attributed to LDRD

48%
2,803 of 5,837 citations of unclassified publications at LANL can be attributed to LDRD

63%
439 of 701 Postdocs at LANL were supported by LDRD

60%
39 of 65 Postdoc conversions at LANL involved LDRD supported Postdocs

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

LDRD funds cutting-edge research that has a large impact on the Laboratory's intellectual property. LDRD projects contribute a disproportionately large share of Los Alamos' overall research outputs. *Those labeled as LDRD supported would not exist without initial work funded by LDRD.*

US Patents

Number of US patents issued in a given FY.

	FY21	FY22	FY23	FY24	FY25
LANL U.S. Patents	46	38	30	26	31
LDRD Supported	14	19	14	14	9
% Due to LDRD	30%	50%	47%	54%	29%

Software Copyrights

Number of software copyrights created in a given FY.

	FY21	FY22	FY23	FY24	FY25
LANL Software Copyrights	120	115	118	136	187
LDRD Supported	48	47	54	52	86
% Due to LDRD	40%	41%	46%	28%	46%

Invention Disclosures

Number of declarations and initial records of an invention (a new device, method, or process developed from study and experimentation).

	FY21	FY22	FY23	FY24	FY25
LANL Disclosures	101	73	72	74	101
LDRD Supported	33	30	26	40	40
% Due to LDRD	33%	41%	36%	54%	40%

THE POWER OF A PATENT

Los Alamos National Laboratory and LDRD have played a central role in advancing space fission power. Both KRUSTY (a Kilopower Reactor Using Stirling Technology concept) and Kilopower emerged from LDRD investments, translating decades of national laboratory nuclear expertise into a compact, flight-ready reactor system. The 1-kW KRUSTY test marked the first U.S. design, build, and ground test of a new reactor concept in more than 50 years and laid the technical foundation for a new generation of space nuclear power systems.

Commercialization and Impact

In 2020, Los Alamos licensed its LDRD-originated Kilopower technology, developed by LANL researchers Patrick McClure and David Poston, to Space Nuclear Power Corporation (SpaceNukes). Building on this foundation, SpaceNukes was recently selected as a commercial partner for the Space Power and Propulsion for Agility, Responsiveness, and Resilience (SPAR) Institute, led by the University of Michigan under the U.S. Space Force University Consortium. In collaboration with the university, SpaceNukes will develop a second-generation reactor with higher operating temperatures and lower mass to support both civilian and defense missions. This partnership demonstrates the successful transition of LANL's LDRD-driven innovations, KRUSTY and Kilopower, from Laboratory prototypes to commercial technologies advancing national security in space. Learn more about this new commercial partnership built on LDRD-funded work here.

NNSA National Nuclear Security Administration

Kilopower: Heat Pipe Reactor Concept to Commercialized Technology

LDRD Los Alamos NATIONAL LABORATORY

R&D Challenge

Space exploration ambitions are increasingly constrained due to a lack of sufficient, reliable power in harsh extraterrestrial environments.

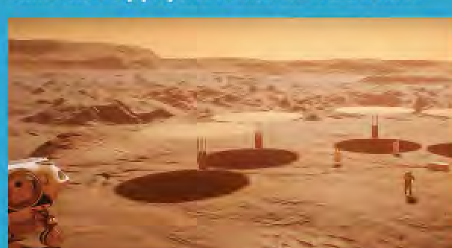
The Challenge:
- Space exploration and future human habitation demand far more reliable power than current systems can provide.
- Solar power is severely limited on Mars due to weak sunlight, long winters, and dust storms, and is impractical beyond Jupiter.
- Existing nuclear options provide only a few hundred watts and rely on scarce, difficult-to-produce plutonium.
- Robotic missions are power-constrained, limiting travel distance and scientific activity.
- Human habitats on Mars would require ~40 kW or more—well beyond what solar or current systems can realistically supply.

2013 R&D 100 WINNER

Approach

LANL teams at Los Alamos and the National Criticality Experiments Research Center (NCERC) worked on developing a small, lightweight, fully autonomous nuclear fission reactor for space. The goal was to develop a reactor design that could;

- Use uranium-235 fission with a solid core, beryllium neutron reflector, and boron carbide control rod.
- Transfer heat via heat pipes (molten sodium) with no moving parts, enabling reliability and simplicity.
- Convert heat to electricity.
- Be passively self-regulating and fail-safe, controlled by physics rather than software.



Artist conception of Kilopower on Mars. Credit: NASA Langley

Impact & Benefit

After developing a successful prototype, LANL partnered with NASA to develop and test Kilopower- a small autonomous reactor that;

- Provides continuous, reliable power (1–10 kW per unit) regardless of sunlight, location, or weather.
- Enables long-duration robotic missions, more energy-intensive science, and far greater exploration range.
- Makes sustained human habitats on the Moon and Mars feasible with scalable, modular power systems.

In 2020, Los Alamos agreed to license the Kilopower technology to Space Nuclear Power Corporation ("SpaceNukes") for commercialized use in space.

SpaceNukes has been awarded several contracts with Air Force Research Lab to develop reactors for space use. The company anticipates bidding on an upcoming NASA fission surface power opportunity.

THE POWER OF A PATENT

It is estimated that demand of hydrogen will surge from less than 2 metric tons currently to over 500 metric tons within 30 years. To meet this challenge, LANL researcher Yu Seung Kim, through LDRD funding, developed an intermediate-temperature electrochemical hydrogen pump (EHP) that enables simultaneous hydrogen separation and compression for blue and biomass hydrogen production. This innovation achieved 99.999% hydrogen purity from a 10% hydrogen/methane mixture with nearly 100% Faradaic efficiency over 1,000 hours. Technoeconomic analysis indicates the potential for up to 95% capital cost reductions and 65% operating cost savings, compared to conventional methods, unlocking new markets such as steel manufacturing, clean ammonia, energy storage, and heavy-duty transportation.

Commercialization and Impact

Following successful laboratory-scale testing, LANL partnered with Gemini Energy in 2025 through an initial test and a partially exclusive license to advance commercialization. The EHP technology offers significant advantages, including high hydrogen production rates, stable operation at 140–200°C, and no moving parts, minimizing downtime and maintenance. EHP's ability to purify and compress hydrogen on-site eliminates the need for costly centralized infrastructure and integrates seamlessly with steam methane reforming plants. These breakthroughs demonstrate how LDRD investments drive transformative innovations, enabling LANL to transition cutting-edge research into commercial technologies that strengthen national security and accelerate the accessibility of hydrogen energy.

NNSA National Nuclear Security Administration | **Intermediate-Temperature Electrochemical Hydrogen Pump (EHP)** | LDRD | Los Alamos NATIONAL LABORATORY

R&D Challenge

Meeting the growing demand for clean hydrogen (H_2) while ensuring cost-effectiveness and technical feasibility presents several critical challenges:

- Scaling up H_2 production dramatically—from very small levels today to hundreds of millions of tons in the coming decades.
- Cutting the cost of blue H_2 enough to make it competitive and open new markets.
- Removing impurities from H_2 when it's mixed with other gases like carbon monoxide and carbon dioxide.
- Creating systems and materials that last longer and perform better than current options.

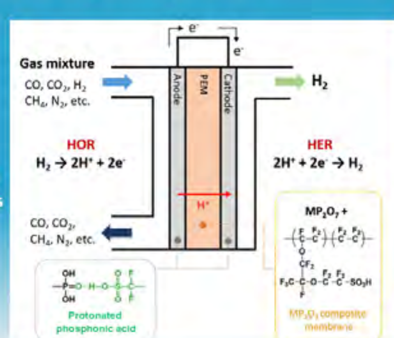
"Industrial hydrogen is the quiet engine behind much of the global economy: refineries, petrochemicals, and steel all depend on it," said Nasser Ghorbani, co-founder and CTO of Gemini Energy. "This exclusive license allows us to transform TRIAD's electrochemical innovation into industrial systems that finally make hydrogen compression and purification efficient, scalable, and profitable."

Approach

Addressing these challenges requires a strategy focused on improving H_2 production, reducing costs, and preparing for large-scale adoption:

- Develop an advanced system that can both separate and compress H_2 efficiently at the laboratory bench scale.
- Ensure the process delivers very high H_2 purity and strong recovery rates from mixed gas streams.
- Demonstrate reliable performance under demanding conditions to prove scalability.
- Use durable materials that outperform current technologies for long-term operation.

The figure depicts the schematic of intermediate temperature electrochemical hydrogen pumps (IT-EHPs).



Impact & Benefit

After successful laboratory scale testing and development, LANL partnered with Gemini Energy in 2025 through an initial test followed by a partially exclusive license to further develop and commercialize the technology in the areas of: refinery and petrochemical, geological hydrogen, fuel-to-power, power-to-fuel, H_2 refueling stations, and pipeline and transportation applications.

Key technology advantages include:
- High H_2 production rate
- Simultaneous H_2 separation and compression simplifying system architecture.
- Separation of H_2 from gas mixtures with less than 20% H_2.
- Stable at 140-200°C operating temperatures.
- No moving parts, which results in lower risk of downtime due to wear and tear.
- Enables on site H_2 purification and compression eliminating need for expensive centralized infrastructure
- Seamless integration with steam methane reforming (SMR) plants

PEER-REVIEWED PUBLICATIONS

The large volume of high-quality peer-reviewed publications produced through LDRD funded work help the Laboratory maintain a strong presence and scientific reputation in the broader scientific community. *Those labeled as LDRD supported would not exist without initial work funded by LDRD.*

Publications

Number of peer-reviewed publications.

Publication Year	FY21	FY22	FY23	FY24	FY25
LANL Publications	2,207	1,929	2,090	1,938	2,157
LDRD Supported	830	796	755	745	830
% Due to LDRD	38%	41%	36%	38%	38%

Citations

Number of times a peer review publication has been cited since the publication year.

Publication Year	FY21	FY22	FY23	FY24	FY25
LANL Citations	52,959	41,064	26,991	15,296	5,837
LDRD Supported	23,449	17,541	11,881	5,905	2,803
% Due to LDRD	44%	43%	44%	39%	48%

LDRD ON THE COVER

The journal cover stories featured here showcase a small but powerful snapshot of the high-impact research supported by the Laboratory Directed Research and Development program. They point to the much broader scientific innovation and discovery enabled by LDRD.

A study recently published in this September 2025 cover article uses computer simulations to understand how water breaks apart on different surfaces of metallic plutonium.

Results show that water can split easily at first, but the oxygen produced binds so strongly to the surface that it quickly blocks further reactions. This suggests that continued water breakdown seen in experiments likely occurs not on bare plutonium metal, but on plutonium oxide that forms on the surface.

Supported by LDRD project: 20230202DR, Understanding Plutonium Corrosion on Machined Surface, PI: Sarah Hernandez

This June 2025 cover article explores how mechanical stretching affects the heat-transfer performance of graphene coatings on copper.

Results show that even small amounts of strain change both how well heat flows within the graphene and how efficiently heat transfers across the graphene–copper interface, as revealed by shifts in Raman measurements. These findings highlight a strong link between mechanical deformation, interfacial contact, and thermal performance in ultra-thin graphene coatings on metals.

Supported by LDRD Projects:

- 20250863ER, Accelerated Qualification of Novel Nuclear Structural Materials: Assessing Irradiation Creep and Irradiation Thermal Fatigue Properties Through In Situ Testing and Multiphysics Simulations, PI: Hi Vo
- 20240473DR, Two-Dimensional Graphene as Corrosion Protection Barrier for Uranium, PI: Youngquiang Wang
- 20230014DR, Discovering Quantum Anomalies Through Strain, PI: Michael Pettes
- 20210036DR, Investigating How Material’s Interfaces and Dislocations Affect Strength, PI: Abigail Hunter

A study recently published in this July 2025 cover article examines how missing tellurium atoms affect the unusual electrical behavior of the layered materials zirconium pentatelluride and hafnium pentatelluride, which can vary widely from sample to sample.

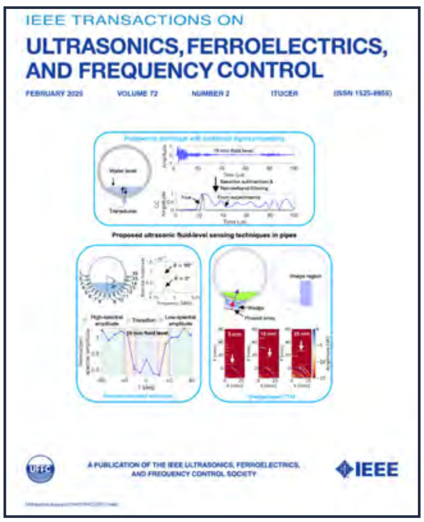
Using computer simulations, the researchers show that these defects change the materials’ electronic structure in ways that help explain previously conflicting experimental results. While the defects contribute to the unusual transport behavior, the findings suggest they do not fully rule out the presence of a more fundamental quantum effect underlying these materials’ properties.

Supported by LDRD project: 20230014DR, Discovering Quantum Anomalies Through Strain, PI: Michael Pettes

This [back cover feature article]() published in the Royal Society of Chemistry in April 2025 describes how machine learning models can be combined with advanced simulation methods to efficiently explore how molecules change shape during chemical processes.

The approach achieves near–quantum-level accuracy at a much lower computational cost and works well for simple test molecules, with accuracy improving further when the models are refined using targeted new data. However, results also reveal limits for more complex molecules, highlighting the need for expert guidance when applying machine learning to challenging chemical problems.

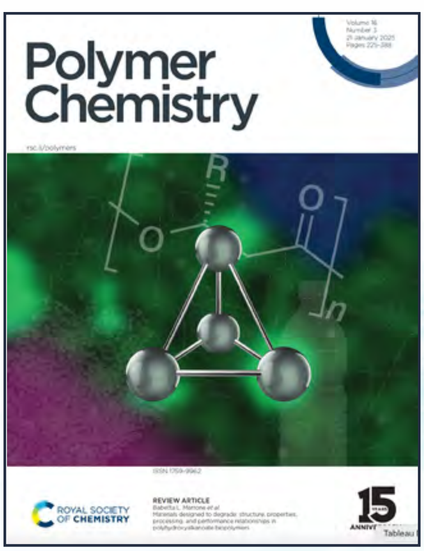
Supported by LDRD Project: 20220801PRD3, Excited State Dynamics: Improving Hamiltonians with Machine Learning, PI: Nikita Fedik



Research published in this February 2025 [cover article]() shows that conventional ultrasonic pulse-echo methods struggle to detect low fluid levels in sealed pipes and introduces a resonance-based approach that remains accurate and sensitive by exploiting fluid-induced attenuation of pipe resonances, validated through simulations and experiments.

To avoid the need for precise calibration, the researchers further proposed a wedge-based phased-array imaging method using total focusing, demonstrating improved low-level fluid visualization with selective artifact filtering.

Supported by LDRD project: 20230468MFR, Acoustic Inspection System for Transuranic (TRU) Waste Handling Activities at LANL Plutonium Facility, PI: Eric Davis



The review published in this January 2025 [cover article]() highlights the environmental problems of conventional plastics and examines polyhydroxyalkanoates (PHAs) as a promising, more sustainable alternative.

The article explores how PHA properties, structure, processing, and performance are connected, while discussing current challenges such as cost, scalability, and limited material options. The authors conclude that continued research could help PHAs play a key role in building a more circular and sustainable plastics economy.

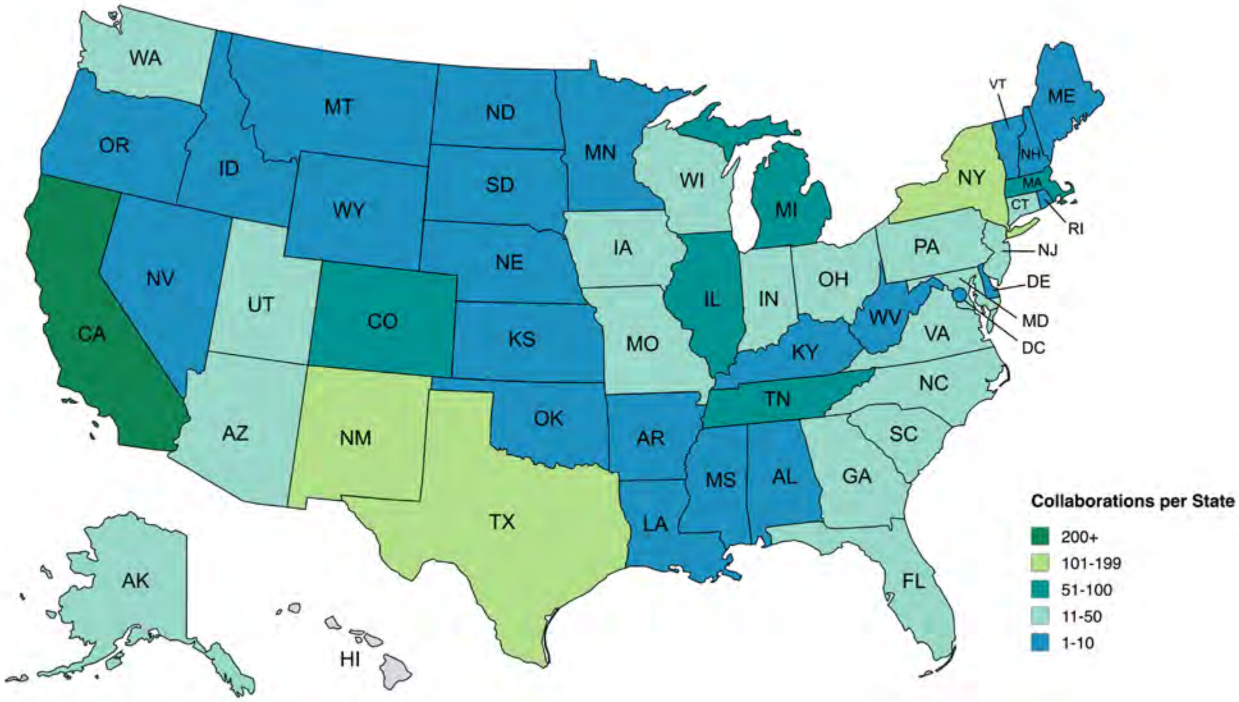
Supported by LDRD Project: 20240001DR, Versatile Synthesis Platforms for Advanced Biomanufacturing (VESPA), PI: Cesar Gonzalez Esquer

BROAD INTELLECTUAL ENGAGEMENT

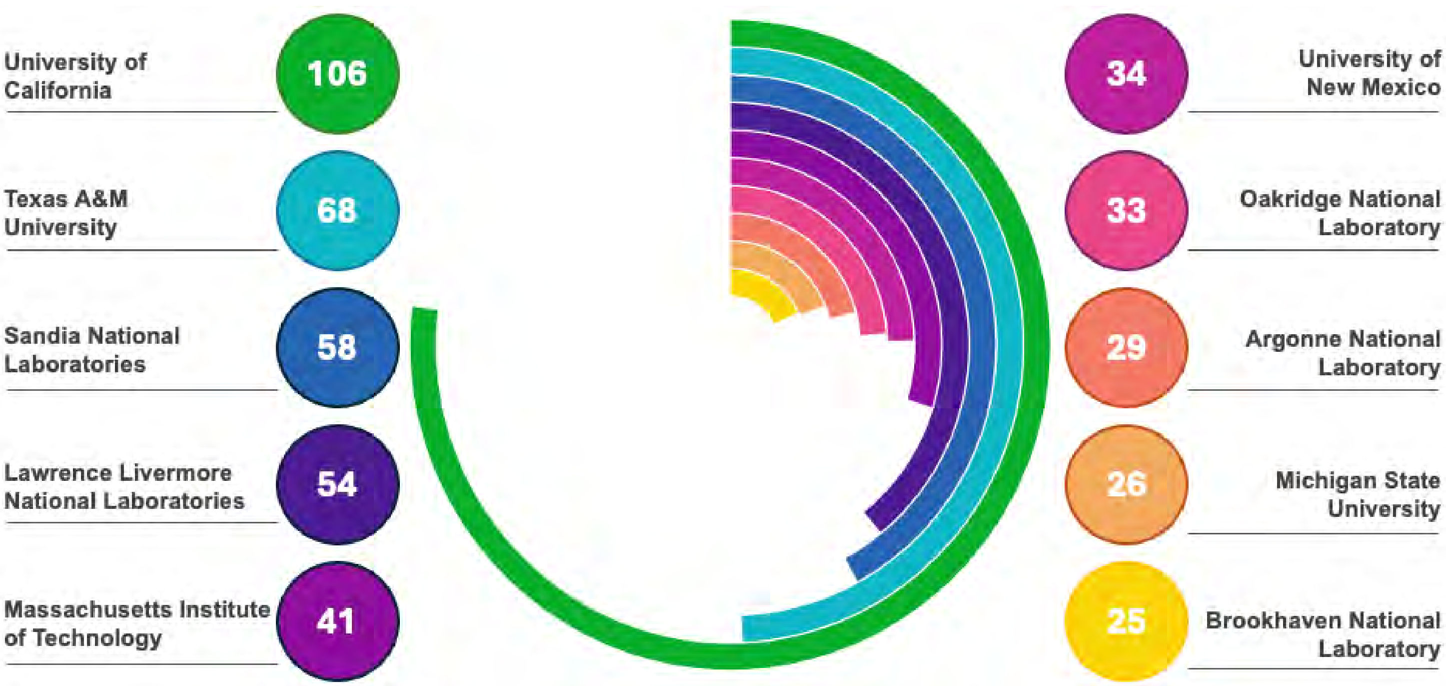
External collaborations are an essential part of LDRD research and development. By working with other national laboratories, academia, and industry, LDRD investigators engage with experts across the Nation and around the world. Most LDRD collaborations involve no exchange of funds, with collaborators using their own funding for mutual benefit and to advance scientific/engineering discovery.

In FY24 and FY25 LDRD researchers reported 1,952 external collaborations; including 1,557 collaborations with U.S. scientists and engineers and 395 with foreign collaborators.

As shown on the map, U.S. collaborations took place in 49 states.



LDRD researchers collaborated with 228 different U.S. organizations. The chart below displays those organizations that had more than 25 reported collaborations.

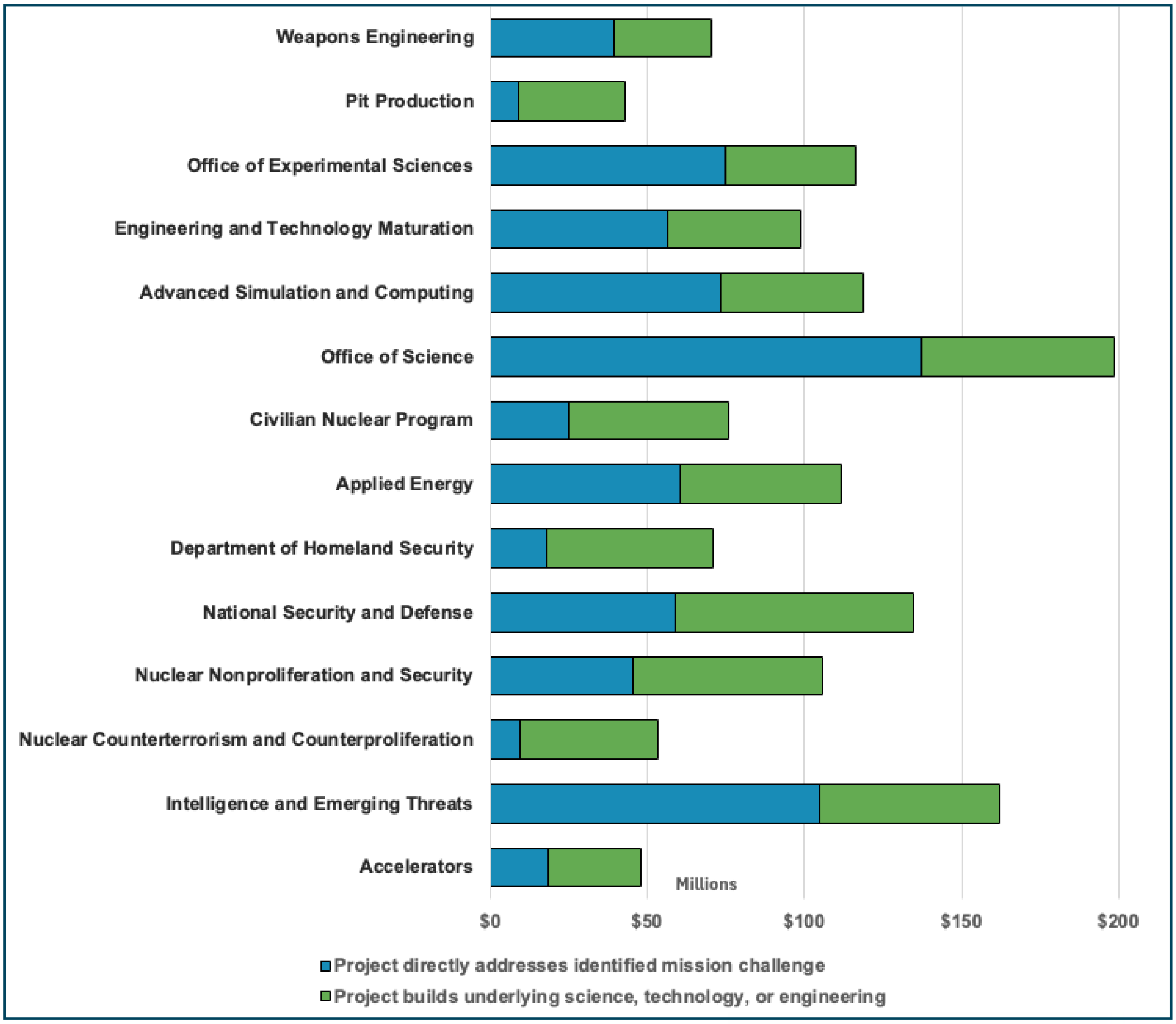


Mission Relevance

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 ST&E innovations from LDRD provide multiple benefits to all Los Alamos stakeholders, consistent with Congressional intent and the Laboratory's technical strategy.

Mission Impact of the FY25 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. The result is that 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.

SCIENCE AND ENGINEERING TALENT PIPELINE

The innovative research and development that LDRD provides is an important vehicle for recruiting the brightest researchers to Los Alamos National Laboratory, where they become technical innovators and 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.

	FY21	FY22	FY23	FY24	FY25
LANL Postdoc	665	652	656	728	701
LDRD Supported	391	389	402	471	439
% Due to LDRD	59%	60%	61%	65%	63%

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.

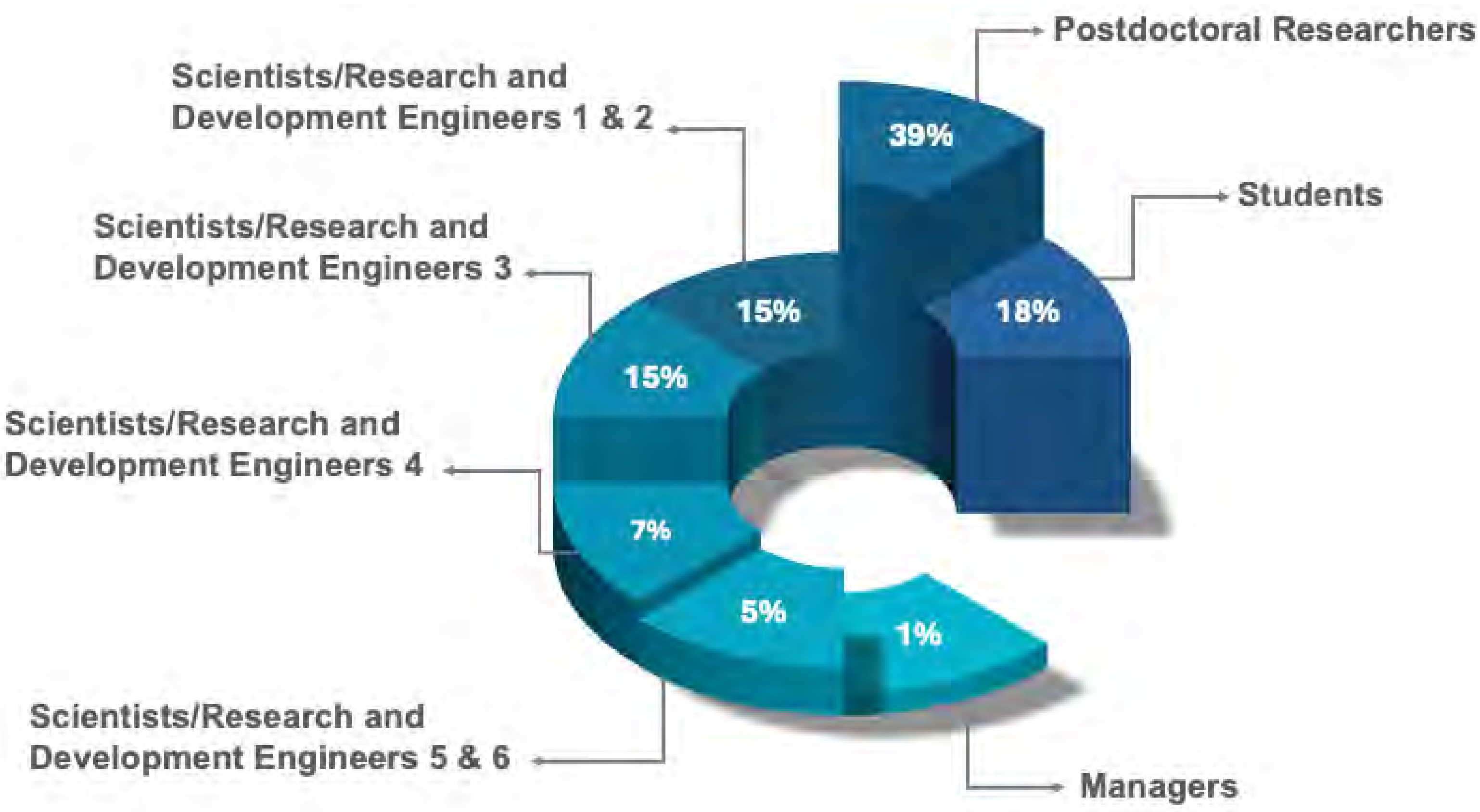
	FY21	FY22	FY23	FY24	FY25
LANL Conversions	81	120	93	101	65
LDRD Supported	44	58	51	56	39
% Due to LDRD	54%	48%	55%	55%	60%

Postdoctoral Researcher Garrett King receives Springer Thesis Award

Garrett King was recently awarded the prestigious Springer Thesis Award for his dissertation, Electroweak Structure and Reactions in Light Nuclei with Quantum Monte Carlo Methods. This international award recognizes a select group of the very best Ph.D. theses worldwide.

King's research applied quantum Monte Carlo techniques to address the nuclear many-body problem and predict nuclear properties– work King has advanced through LDRD and DOE/SC projects at LANL. As a Director's Postdoctoral Fellow, King also organized the workshop Future Directions in Nuclear Beta Decays at the Facility for Rare Isotope Beams (FRIB) under the Theory Alliance.

LDRD INVESTS IN EARLY CAREER STAFF



LDRD plays a critical role in attracting, developing, and retaining an exceptionally talented and creative workforce capable of addressing some of our Nation's most challenging problems. The graphic above illustrates the percentage breakdown of labor hours charged to LDRD in FY25 by students, postdoctoral researchers, scientists, research and development (R&D) engineers, and managers. As highlighted by the darker blue wedges, more than 70% of these hours were contributed by early-career staff, postdocs, and students, underscoring LDRD's commitment to fostering the next generation of scientific and engineering leaders.

In FY25:

- 18% of total labor hours were charged by students.
- 39% were charged by postdoctoral researchers.
- 15% were charged by Scientists/R&D Engineers 1 & 2.

It is not uncommon for them to continue contributing important R&D to a research project. In FY25, approximately 1% of total hours charged to LDRD were by managers actively working on LDRD projects.

EARLY CAREER SPOTLIGHTS

William Taitano and Ingo Tews

Two LDRD Researchers win DOE Early Career Research Program Awards

Will Taitano and Ingo Tews, both from LANL's Theoretical division, each won a DOE Early Career Research Program award, which provides five years of funding for an R&D project relevant to an Office of Science program area of importance to basic energy sciences.

Will, who has led two LDRD projects, including an FY19 LDRD Early Career Research project, will be leading a DOE project that is focused on formulating a simpler way to solve the Boltzman equation, which could lead to better, more reliable transport simulations.

Ingo, who has led six LDRD projects, including an FY22 Early Career Research project, will be leading a DOE project that is developing new models of nuclear interactions and using artificial intelligence to improve quantum simulations to better understand neutron stars and their mergers.

"Will and Ingo are addressing some of the most challenging problems in computational and theoretical physics," said Laboratory Director Thom Mason. "Their selection for DOE Early Career Research Awards reflects their promising careers and the Lab's leadership in tackling the foundational science that underpins our national security mission."

Data shows that LDRD experience is a strong precursor to DOE Early Career Award success. ***94% of LANL staff*** *who have received DOE Early Career Awards since 2015 led an LDRD project prior to the award. Further analysis shows that 75% of LANL staff led LDRD Early Career Research (ECR) projects prior to receiving the award. This strong alignment highlights LDRD's role in providing early-career researchers with critical opportunities for scientific leadership, proposal development, and independent research—building the capabilities, visibility, and track record that support national recognition and long-term career success.*

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 five 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 and 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 alone.

Tracing Impact Back to LDRD

Throughout this section, we will be sharing metrics that illustrate the long-term impact of "LDRD roots." There is often a lot of discussion regarding 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. 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, 90% 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		Ten Years
	FY23	FY24	FY25	FY16-FY20	FY21-FY25	FY16-FY25
Total Awards	1	2	1	30	10	40
Awards with LDRD Roots	1	2	1	28	8	36
% with LDRD Roots	100%	100%	100%	93%	80%	90%
Average Years from First LDRD Experience	10	25	9	11.82	16	12.75

LANL Researcher Elected 2025 APS Fellow has LDRD Experience

Larry Hill *was named a 2025 American Physical Society Compression of Condensed Matter Fellow. This fellowship recognizes Hill's "groundbreaking contributions to the innovative design and execution of shock physics experiments involving energetic materials, pioneering insights into the microstructural effects of high explosives, and significant advancements in the theoretical understanding of shock and detonation physics." The fellowship honors "APS members who have contributed to the advancement of physics by independent, original research to the cause of the sciences."*

Hill is an internationally recognized authority on the experimental and theoretical behavior of high explosives. Over the past 33 years, his work has advanced research in areas ranging from process–structure–performance relationships in next-generation high-explosive formulations to cutting-edge, physics-based experiments that enhance understanding and characterization of detonation phenomena. Hill's work in LDRD first began in 2016 a Co-Investigator of a Directed Research project.

Top 2%

Recognition as an esteemed member of the technical staff in a science, technology, and engineering (ST&E) field signifies a high level of career achievement. At LANL, individuals who attain this distinction are designated as Fellows. The term "Top 2%," used here as shorthand, reflects the intent across the Laboratories to limit Fellowship to approximately the top 1–2% of scientific and technical staff. These Top 2% awards are comparable to a lifetime achievement honor, recognizing sustained and significant contributions to the Laboratory's mission.

In FY25, six of the eight 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 15 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		Ten Years
	FY23	FY24	FY25	FY16-FY20	FY21-FY25	FY16-FY25
Total Awards	9	7	8	27	37	64
Awards with LDRD Roots	9	7	6	25	34	59
% with LDRD Roots	100%	100%	75%	93%	92%	92%
Average Years from First LDRD Experience	11.56	16.8	20.8	14.85	15.6	15.2

Six LANL Researchers Elected 2025 Fellows have LDRD Experience

***James Colgan**, of the Theoretical division, was named fellow for his sustained, outstanding scientific leadership in the field of atomic and molecular physics. He is a recognized international leading authority in the modeling of atomic processes in plasmas and the production and use of opacities for a range of applications that contribute to the Laboratory's national security mission. He has authored more than 250 papers and more than 20 Physical Review Letters. Colgan's work in LDRD first began in 2008 as a Co-Investigator of a Directed Research project.*

***Franz Freibert,** of the National Security Education Center and director of the G.T. Seaborg Institute, was named fellow for groundbreaking achievements in plutonium and actinide materials science, condensed matter physics, and materials production research and characterization. His contributions have enhanced current weapons physics and engineering performance methods. He fundamentally influenced the Laboratory's nuclear defense mission and actinide science reputation. Freibert has 106 peer-reviewed publications. Freibert's work in LDRD first began in 2011 as a Co-Investigator of a Directed Research project.*

(continued on next page)

LANL Researchers Elected 2025 Fellows have LDRD Experience

Bryan Henson, *of the Physical Chemistry and Applied Spectroscopy group, was named fellow for sustained, high-level achievement in advancing the understanding of the chemistry and physics of molecular condensed phases, with applications including ozone depletion and explosives. His insights into explosive thermal response have influenced work throughout the National Nuclear Security Administration, internationally. Henson has published more than 100 papers with thousands of citations. Henson's work in LDRD first began in 1996 as the PI of an Exploratory Research project.*

Toshihiko Kawano, *of the Nuclear and Particle Physics, Astrophysics and Cosmology group, was named fellow for his scientific contributions that have transformed the field of nuclear data. He is one of the world's foremost scientists in nuclear reaction physics and nuclear data, and his contributions span from fundamental theory to Laboratory mission-critical applications. He has more than 170 publications in peer-reviewed journals. Kawano's work in LDRD first began in 2005 as a Co-Investigator of a Directed Research project.*

Charles Reichhardt, *of the Quantum and Condensed Matter Physics group, was selected as a fellow for advancing the understanding of physics underlying a variety of non-equilibrium phenomena, the role of topological defects such as vortices and skyrmions, active matter. His work comprises roughly 350 peer-reviewed publications, which are highly cited. Reichhardt's work in LDRD first began in 2006 as a Co-Investigator of an Exploratory Research project.*

Tom Vestrand, *of the Space Remote Sensing and Data Science group, was named fellow for seminal discoveries in gamma-ray astronomy, high-energy solar physics, and optical time-domain astronomy. Vestrand led the development of the RAPid Telescopes for Optical Response system of robotic telescopes and the Thinking Telescopes project that paved the way for a new generation of autonomous optical telescopes that monitor the night sky for powerful cosmic explosions. Vestrand's work in LDRD first began in 1999 as the PI of an Exploratory Research project.*

2025 American Association for the Advancement of Science Fellow Award

Jeffrey Pietryga *has been named a fellow of the American Association for the Advancement of Science. Members of the world's largest professional society — scientists, engineers and innovators from across disciplines — are named fellows in recognition of their lifetime efforts to advance science or its applications. A longtime chemist at the Laboratory, Pietryga was recognized by the AAAS "for formative contributions to the synthetic chemistry of advanced nanocrystal quantum dots," as well as "enthusiastic leadership and advocacy of science in the national interest."*

"Jeff's research has been invaluable in the development of effective, lower-cost photovoltaics that find applications in critical technologies." said Patrick Fitch, deputy director for Science, Technology, and Engineering at Los Alamos.

Currently the program manager for university collaborations at the Laboratory, Pietryga's career at Los Alamos includes nearly a decade as the novel nanomaterials thrust leader at the Center for Advanced Solar Photophysics, an Energy Frontier Research Center. He helmed the operational coordination of center research activities and conducted research in advanced infrared-active nanomaterials. He continued active research while serving as deputy group leader for the Physical Chemistry and Applied Spectroscopy group at the Laboratory. Pietryga then moved into a full-time management position as group leader for the Inorganic, Isotope and Actinide Chemistry group until 2024, when he joined the National Security Education Center at the Lab, creating and fostering relationships with academic partners. Pietryga's work in LDRD first began in 2007as a Co-Investigator of an Exploratory Research project.

2025 Society for Industrial and Applied Mathematics Fellow Award

The Society for Industrial and Applied Mathematics (SIAM) has selected nuclear engineer ***Luis Chacón*** *of the Theoretical Division at Los Alamos National Laboratory for its 2025 class of Fellows. Chacón was recognized "for seminal contributions to scalable, multiscale fluid, kinetic, and hybrid algorithms, enabling breakthrough simulations of magnetic and inertial fusion plasmas."*

Chacón joined the Laboratory's Theoretical Division as a Director's Postdoctoral Fellow in 2000 and became a staff member in 2002. His research focuses on the development of multiscale algorithms for fluid and kinetic plasma modeling, with applications to basic plasma science as well as inertial confinement fusion and magnetic fusion. He earned his doctorate in nuclear engineering from the University of Illinois at Urbana–Champaign in 2000 and has received numerous honors, including being named a Fellow of the American Physical Society in 2020, receiving the Ernest O. Lawrence Department of Energy Award in 2021, and being selected as a Los Alamos National Laboratory Fellow in 2024. Chacon's work in LDRD first began in 2004 as the PI of an Exploratory Research project.

2025 Royal Society of Chemistry Fellow Award

Theoretical scientist ***Ping Yang*** *was admitted as a Fellow of the Royal Society of Chemistry in the United Kingdom in recognition of her years of experience in senior scientific roles and her significant contributions to the chemical sciences. Yang works in the Physics and Chemistry of Materials group, where she conducts theoretical research spanning atoms, molecules, solids, liquids, gases, and plasmas. She was recognized in particular for her longstanding contributions to heavy element chemistry and separation sciences. Her research has advanced scientific understanding of the unique chemical bonding, electronic structures, and dynamic behaviors of f-element systems, including radioactive elements and lanthanides at the bottom of the periodic table. She also pioneered the use of autonomous discovery in f-block chelation chemistry for cancer therapy, expanding possibilities for actinide separation and broader chemical innovation.*

Yang currently serves as deputy director of the Laboratory's Glenn T. Seaborg Institute for Transactinium Science, which integrates research on the chemical, physical, nuclear, biological, and metallurgical behaviors of lighter actinide elements, with a particular emphasis on plutonium. Over the course of her career, she has published more than 160 peer-reviewed articles in leading journals and has supervised and mentored more than 60 postdoctoral researchers and graduate students. Yangs' work in LDRD first began in 2019 as a Co-Investigator of a Directed Research project.

2025 American Nuclear Society Fellow Award

Chris Stanek, *the director of Nuclear Energy Programs at the Laboratory, has been named a fellow of the American Nuclear Society. Stanek earned the distinction of fellow for his "pioneering contributions to fuel and materials research and his exceptional leadership in advancing modeling and simulation for nuclear energy."*

Stanek manages projects that use and build civilian nuclear research and technology capabilities to advance nuclear energy science. He was the national technical director of the Department of Energy's Nuclear Engineering Advanced Modeling and Simulation program from 2015-24, where he helped develop modeling and simulation tools to accelerate the deployment of advanced nuclear energy technologies. Before leading the NEAMS program, he led the nuclear materials and fuels research effort for the Consortium for Advanced Simulation of Light Water Reactors, a DOE Energy Innovation Hub that partners government, industry and academia for research and technology development in the nuclear energy enterprise.

Stanek's research interests have focused on the interaction between multidimensional defects in ceramics, primarily via atomistic simulation techniques, with a particular interest in materials for nuclear energy, including transmutation fuels, crystalline waste forms and scintillator radiation detectors. He has published more than 120 papers on using computational materials science methods to study materials important to the nuclear fuel cycle and has an h-index of 47. He serves as an associate editor of the Journal of Nuclear Materials and is a member of the editorial advisory board for the journal Nuclear Engineering and Design. Stanek's work in LDRD first began in 2008 as a Co-PI of a Directed Research project.

2025 American Statistical Association Fellow Award

Brian Weaver *of the Computer, Computational and Statistical Sciences Division at Los Alamos National Laboratory has been elected a Fellow of the American Statistical Association (ASA) in recognition of his distinguished service and sustained commitment to advancing the field of statistics. The ASA is the world's largest professional community of statisticians and data scientists, with members spanning industry, government, and academia in more than 90 countries. Newly elected Fellows will be formally recognized at the Joint Statistical Meetings in Nashville this August. Weaver was selected "for exemplary leadership in the development of statistical methods in national security science, for major collaborations that have advanced the physical sciences, and for sustained impact on the ASA through a dedicated history of strategic service."*

Weaver leads the Statistical Sciences group (CCS-6), which supports a broad portfolio of science, technology, and engineering projects aligned with national and global security missions. His research includes the application of artificial intelligence and machine learning to challenges in weapons science, space physics, planetary science, and nuclear safeguards. He holds a doctorate in statistics from Iowa State University. Weaver's work in LDRD first began in 2019 as a Co-Investigator of an Early Career Research project.

2025 Optica Fellow Award

Diego Dalvit, *a scientist in the Theoretical Division, was elected a Fellow of Optica in recognition of his "distinguished contributions to the advancement of optics and photonics," according to the society. Optica, formerly known as the Optical Society of America, is a leading professional organization dedicated to the science of light. Dalvit's election recognizes his expertise across a wide range of physics and quantum physics topics, including outstanding theoretical contributions to electromagnetic quantum fluctuations and quantum optics in metamaterials, plasmonic surfaces, and other nanostructured materials.*

Over the course of his career, Dalvit has authored more than 100 peer-reviewed papers that have received over 9,000 citations and has co-authored two physics textbooks—one focused on the foundations of Casimir physics and another on statistical mechanics. His work has also led to one issued patent and a second patent submission in 2024 related to the development of quantum remote sensing technology. In addition to his research contributions, Dalvit has helped convene more than 50 talks, seminars, and related activities, served on committees supporting Laboratory programs, and acted as a reviewer for funding agencies and scientific journals. He has organized seminars, workshops, and schools on quantum physics topics and has mentored postdoctoral researchers and graduate students for nearly three decades. He has also been recognized as a Fellow of the American Physical Society in 2015 and was named an Outstanding Referee by the society in 2022. Dalvit's work in LDRD first began in 2007 as a Co-PI of a Directed Research project.

R&D 100 Awards

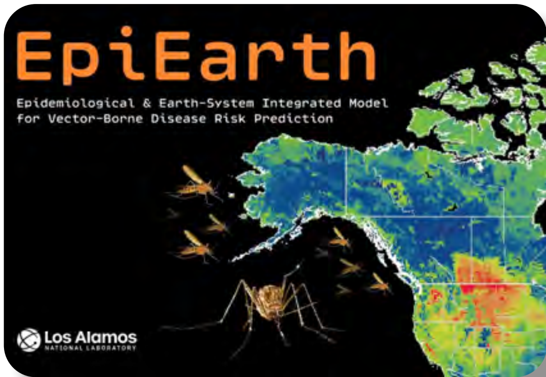
A relevant indicator of advancement and leadership in an ST&E field is the R&D 100 Award. The prestigious "Oscars of Invention" honor the latest and best innovations and identify the top technology products of the past year. The LDRD Program Offices at each site often partner with sister organizations, 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 an 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 FY25, all three of the 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 majority of R&D 100 winners with prior LDRD experience. Of the 75 R&D 100 awards received by LANL since FY16, 47 have roots in LDRD.

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

	Single-Year Statistics			Five Years		Ten Years
	FY23	FY24	FY25	FY16-FY20	FY21-FY25	FY16-FY25
Total Awards	9	8	3	39	33	75
Awards with LDRD Roots	5	6	3	23	24	47
% with LDRD Roots	56%	75%	100%	59%	73%	63%
Average Years from First LDRD Experience	4.8	3.5	5.6			

In 2025 Los Alamos received three R&D 100 winners. All three of the awards have roots in LDRD.



EpiEarth: Epidemiological and Earth-System Integrated Model for Vector-Borne Disease Risk Prediction

This software tool enables the prediction of disease spread by vectors (mosquitoes, ticks, etc.), risk and the impact of mitigation efforts on potential epidemics. EpiEarth provides the detail necessary to give public health decision-makers the tools to respond to an outbreak and the information to understand how a particular intervention strategy will work immediately and over time. The flexible design allows substitution of different models, diseases, hosts or vector species, making the tool generalizable across diseases that affect human, livestock and crop health. EpiEarth also won the Gold Medal Special Recognition Award for Corporate Social Responsibility.

Carrie Manore directed the Los Alamos team of Jeanne Fair, Chonggan Xu, Adam Atchley, Andrew Bartlow, Ryan Crumley, Sara del Valle, Geoff Fairchild, Humberto Godinez Vazquez, Morgan Gorris, Kim Kaufeld, Tammie Lopez, Marina Mancuso, Kaitlyn Martinez, Gul Nair, Nidhi Parikh, Ethan Romero-Severson, Jon Schwenk, Julie Spencer, Xiaming Sun, John Tipton, Amanda Ziemann and former Los Alamos researchers. Watch the video.

PAD-TIE: Platform to Accelerate Discovery of Tailored Industrial Enzymes

This rapid, low-cost, simple screening toolkit evolves enzymes in a laboratory setting to develop enzymes optimized for industrial applications. The patent-pending technology scans many enzyme variants to discover highly efficient enzymes tailored for industrial use — making industrial processes, such as breaking down plastic to its building block molecules, more efficient and economical. PAD-TIE also won the Bronze Medal Special Recognition Award for Green Tech.

Hau Nguyen led the Los Alamos team of Thomas Groseclose and Taraka Dale. Watch the Video.

GeoDTi: Geothermal Design Tool Interactive

This commercially copyrighted software provides a one-stop shop for geothermal energy prospecting and design optimization by incorporating physical and economic inputs to help stakeholders and decision-makers optimize geothermal energy. GeoDTi incorporates the physics of faults and fractures to answer critical questions about the relative performance of different locations, well layouts and flow rates to assure a maximum return on investment. Corporations, universities and national labs already use GeoDTi to evaluate geothermal energy development. GeoDTI won the Silver Medal Special Recognition Award for Green Tech.

Luke Frash led the Los Alamos team of Bulbul Ahmmed and Bijay KC. Watch the video.

LDRD Program Accomplishments

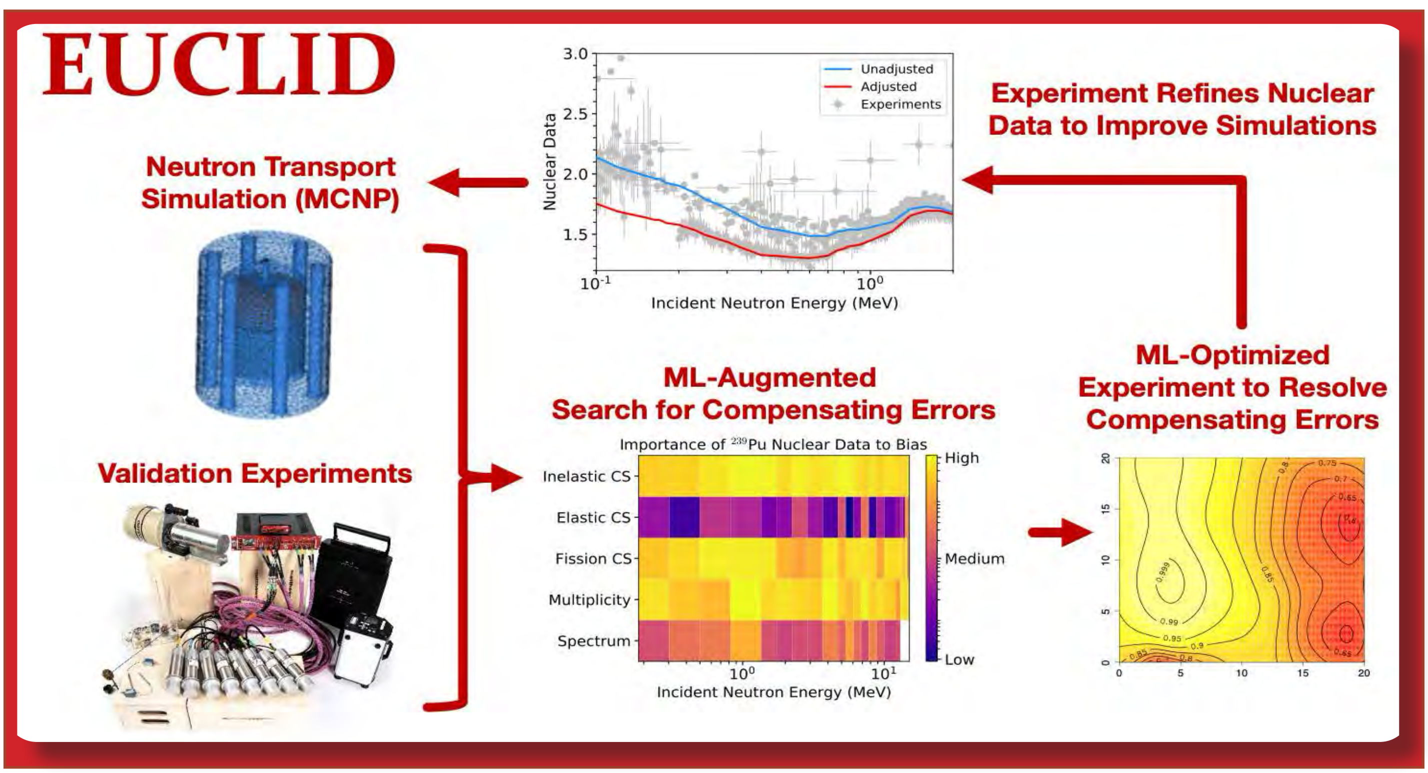
Top Science in the News

AI can help scientist get the nuclear data they need for vital simulations

LAB SCIENTISTS ARE USING AI TO GUIDE THE DESIGN OF CRITICALITY EXPERIMENTS.

Predictive simulation is one of the things that Los Alamos does best. It is a primary tool for studying nuclear reactors, nuclear weapons, astrophysics, criticality safety, and more. These simulations of the most dynamic processes in the universe go hand in hand with experimentation: Experiments produce the data that go into the simulations, and the simulations guide the design of subsequent experiments—so the data used in simulations must be as high quality as possible. A recent LDRD project, called EUCLID (Experiments Underpinned by Computational Learning for Improvements in nuclear Data), used machine learning (ML) and artificial intelligence (AI) to get high-quality data faster for some of the Lab's most vital missions.

Criticality experiments on plutonium are done at the National Criticality Experiments Research Center (NCERC), a Department of Energy facility in Nevada. These elaborate experiments involve bringing plutonium to the point of criticality, the state in which a fission chain reaction is self-sustaining, with the number of neutrons generated being equal to the number lost. The reaction is self-sustaining but not uncontrolled. "It's not like a nuclear weapon; there's no yield," assures Jesson Hutchinson, a Los Alamos nuclear engineer who led the EUCLID project. "It's more like a mini reactor, so low in power that we don't even need a cooling system."



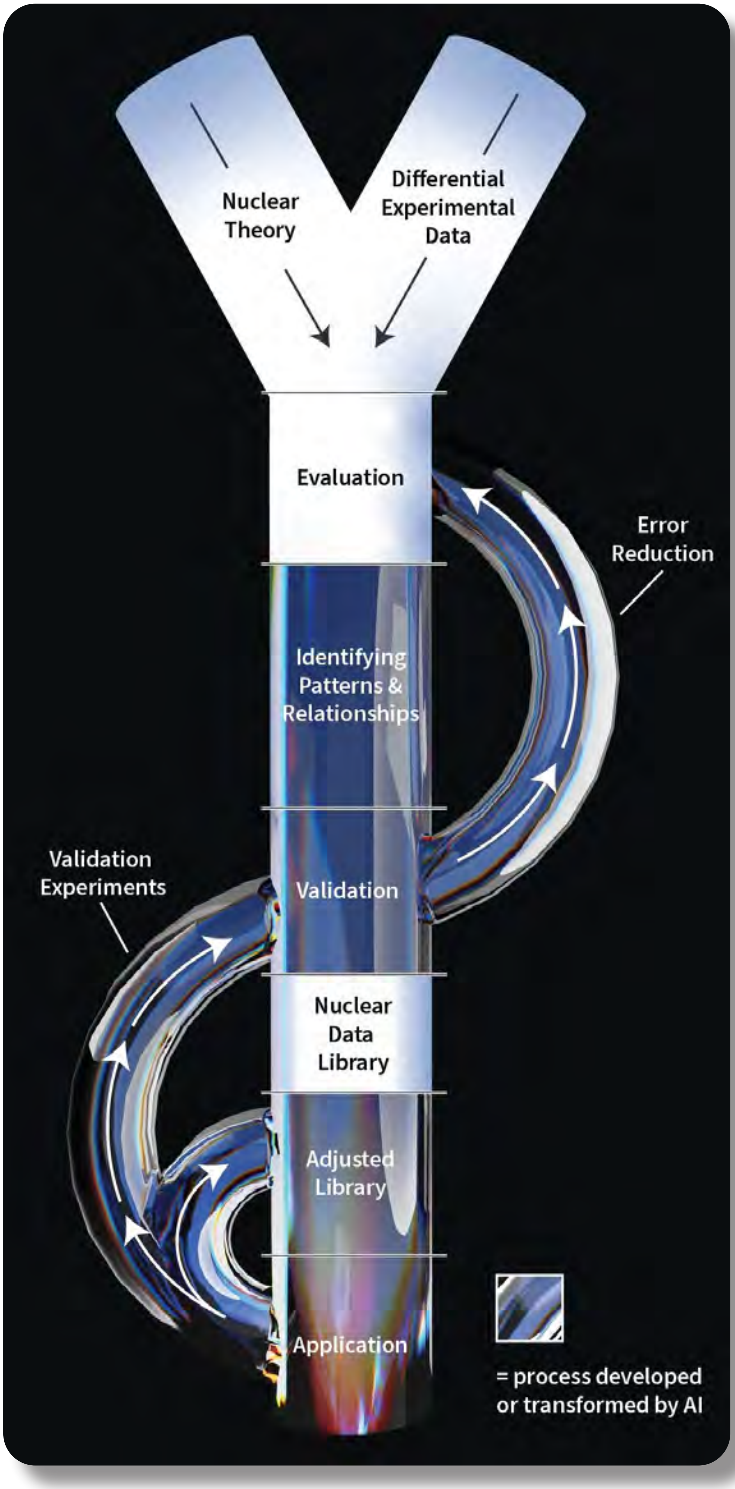
Compensating errors within nuclear data can adversely impact application simulations, but cannot be resolved using current techniques. EUCLID utilized machine learning (ML) with simulated sensitivities in Monte-Carlo N-particle (MCNP) of experiments and measured results to augment expert identification of areas where compensating errors may be resolved.

Broadly, the terms ML and AI are becoming less interchangeable, with ML trending toward automated pattern recognition and AI trending toward large-language models that mimic human intelligence. EUCLID used both: first, ML to identify nuclear data in need of improvement, then, AI to design an experiment to produce the improved data. The end goal of EUCLID and several related projects is to provide the Lab with two new ML/AI-based, mission-focused capabilities: a tool to reduce errors in nuclear data and a new way to design criticality experiments.

Nuclear data are used by simulations to predict what reactions will happen under various conditions. "Data from different experiments are combined into one big data set called a library," explains Denise Neudecker, a Los Alamos nuclear physicist in charge of the nuclear data work for EUCLID. "So, you can model things like weapons, reactors, and astrophysics and ask, 'What will happen if I shoot this with that?' and the model will pull data from the library and predict how many neutrons will be produced and whether it will be subcritical, critical, or supercritical."

But nuclear data libraries don't come straight from experiments; they are processed through a pipeline that combines experimental data with nuclear theory. Once processed, the data must be validated through further experiments before being made available to researchers worldwide.

This process has several shortcomings that EUCLID aimed to remedy. First, libraries aren't as transferable as they could be because data is manually tuned to specific experiments, and the hand-tuning done for one experiment can become errors for a different experiment. Second, because of its complexity, criticality experiment design is iterative and time-consuming. Finally, the process is designed and evaluated by human brains, so it's inefficient,



The nuclear data production pipeline combines experimental data and nuclear theory to produce nuclear data libraries. Traditionally, the process involves hand-tuning data to particular applications, which can introduce errors when the library is used for a different application. Lab scientists have recently shown that ML and AI methods can improve the pipeline in two ways: First, ML can find patterns in nuclear data that humans cannot, making it a powerful means of reducing error, and second, AI can help design, much faster and more comprehensively than a human brain can, the experiments used to validate nuclear data libraries.

and new nuclear data libraries are only released about every 10 years, meaning when new questions come up, the answers may be based on old information.

EUCLID used simulation and experimentation to show that key segments of the nuclear data pipeline can be automated and enhanced. It was a crucial proof of concept: By reducing errors, there is less iteration, so the validation experiments match predictions sooner. The time to produce a new library could be brought down from 10 years to just three years.

"We used ML and AI in two ways," says Mike Grosskopf, who led the ML/AI aspect of the project. "First, to identify sources of error, and second, to design an experiment that would improve the data."

For the error-finding part of EUCLID, the scientists were interested in whether nuclear data were related, and how. They used ML and ML-interpretability methods to identify relationships and patterns in the data. ML interpretability has to do with human understanding of what the ML model did and why.

To test their idea, the team wanted to identify one error-prone thing to try and fix. ML indicated that fast nuclear data for plutonium-239 (239Pu) was something that criticality experiments were sensitive to. These are data from processes including fission and scattering of a 239Pu nucleus upon absorbing a neutron, so the team decided to use that as their target for error reduction.

For the experimental design part of EUCLID, AI was used to design a criticality experiment that would reduce errors in the fast nuclear data for 239Pu. Through a sequential approach known as Bayesian optimization—an AI model would evaluate a set of particle transport simulations for criticality and propose a design, then the scientists would run a new simulation, reupdate the model, and have it propose a modified design—the team eventually arrived at the design for a new criticality experiment, which was conducted in early 2023 at NCERC.

The experiment consisted of two configurations of 239Pu, one to maximize neutron leakage and one to minimize it. For each configuration, two subcritical masses of 239Pu were brought into proximity with one another via remote control until criticality was achieved. Over the next 10 minutes, neutrons streamed silently into detectors, carrying with them key information about the systems' criticality. We really want to use AI in places where the human brain can't go.

The team used the collected data for new particle transport simulations and calculated the uncertainty. The data were analyzed by Neudecker and other experts in the loop, then adjusted and assessed as to whether there were significantly fewer errors. There were. But the data also revealed previously unknown details about 239Pu scattering that are now being looked at more closely, including an overestimation of more than 10 percent for one variable.

Another follow-on LDRD project, led by Neudecker, is PARADIGM (PARallel Approach of Differential and InteGral Measurements). "Whereas EUCLID was focused on criticality experiments, PARADIGM is focused on speeding up the entire pipeline, especially for intermediate energy ranges, which are the least well understood," she explains. PARADIGM will bring Los Alamos and NCERC experiments together, but the novelty is how the experiments will be selected: The team is using AI methods to understand which combinations of theory and experiment will best reduce uncertainty in nuclear data.

This work was supported by LDRD project 20210021DR led by Jesson Hutchinson, and by LDRD project 20240031DR led by Denise Neudecker.

Read the full article by Eleanor Hutterer here.

Experiments Underpinned by Computational Learning for Improvements in nuclear Data (EUCLID)

Los Alamos NATIONAL LABORATORY

R&D Challenge

LDRD's EUCLID project aimed to develop machine learning (ML) methods with embedded physics constraints, leveraging new experimental data to deliver improved nuclear information at an unprecedented rate.

The Challenge:

- Predictive simulations depend on nuclear data that can contain hidden errors and uncertainties.
- Nuclear data libraries are manually tuned, making them less transferable across experiments and prone to bias.
- Designing and validating criticality experiments is complex, iterative, and time-consuming.
- Human-driven processes limit efficiency, with new nuclear data libraries released only about every 10 years.
- Inconsistent uncertainties across libraries can lead to conflicting simulation outcomes.

"We wanted to look for places to use AI where the brain can't go or is overloaded with information. AI is not a magic wand; it's a tool that can find trends in data that the human brain cannot." Co-PI: Denise Neudecker

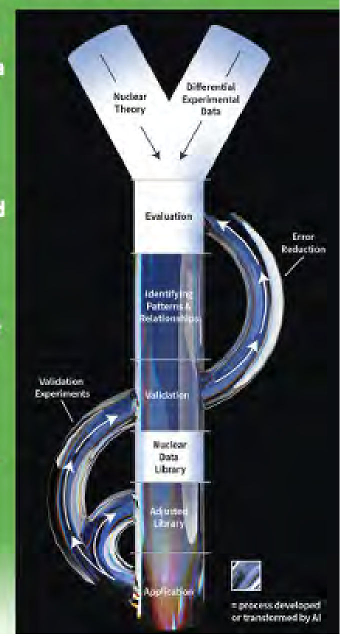
Approach

To address these challenges, the EUCLID team-spanning LANL, the National Criticality Experiments Research Center, and the Department of Energy-combined advanced ML, artificial intelligence (AI), and domain expertise in a tightly integrated workflow.

- Team members applied machine learning to identify error-prone nuclear data and uncover hidden relationships within nuclear data libraries.
- They used AI-driven experiment design, including Bayesian optimization, to iteratively propose and refine criticality experiment configurations.
- Based on ML insights, the team focused on fast nuclear data for plutonium-239, which strongly influences criticality simulations.
- Simulation, experimentation, and expert human interpretation were linked in a closed-loop process to validate results and drive refinement.

Impact & Benefit

EUCLID demonstrated that applying AI and ML to the nuclear data pipeline can reduce uncertainties, cut nuclear data library development from roughly a decade to just a few years, improve agreement between simulations and experiments, uncover new insights into plutonium-239, and deliver enduring, mission-focused capabilities for national security science.



Shifting the Nuclear Data Evaluation PARADIGM: PARallel Approach to Differential and InteGral Measures (PARADIGM)

Los Alamos NATIONAL LABORATORY

R&D Challenge

Understanding nuclear data (ND) at intermediate energies (10-100 keV) remains one of the most pressing issues for LANL missions. These uncertainties hinder accurate predictive simulations and critical analyses. LDRD's PARADIGM project will reduce large ND uncertainties at intermediate energies.

The Challenge:

- ND at intermediate energies fore key isotopes like uranium-235 and plutonium-239 remain highly uncertain.
- These uncertainties impact critical LANL missions, including nuclear weapons safety analysis, science-based stockpile stewardship, and subcritical experiments.
- Traditional approaches design differential and integral experiments independently, limiting efficiency and precision.

Approach

PARADIGM introduces a groundbreaking strategy that combines advanced theory, machine learning (ML) and joint experimental design to overcome these limitations.

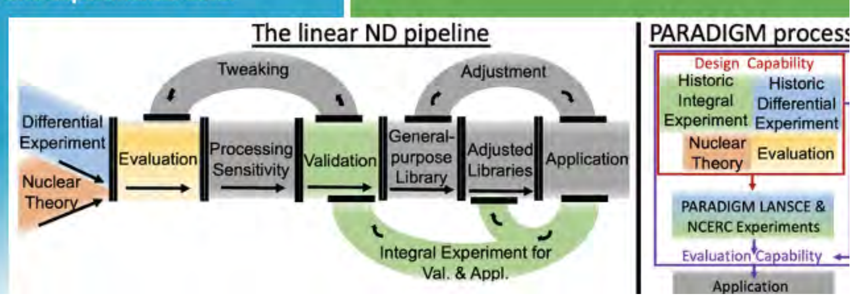
The PARADIGM project:

- Introduces a paradigm shift by jointly designing differential and integral experiments using ML.
- The project combines novel nuclear theory with artificial intelligence (AI)-driven experiment selection to optimize uncertainty reduction.
- The project is also developing the first ML-supported ND evaluation technique integrating advanced theory and experimental data.

Impact & Benefit

By reducing uncertainties and accelerating timelines, PARADIGM delivers transformative improvements to nuclear data quality, strengthening mission-critical applications and setting a new standard for future evaluations.

- 50% reduction in nuclear data uncertainties at intermediate energies.
- Accelerated timeline for delivering optimized ND for LANL missions.
- Improved predictive simulations for high-priority applications.
- Evaluation through AI-driven design and integration.



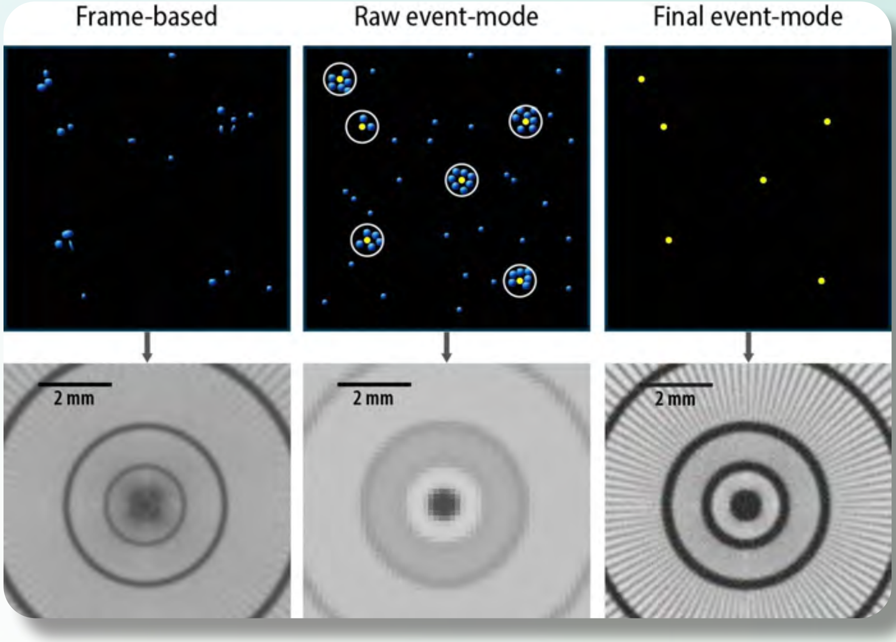
TOP SCIENCE IN THE NEWS

Crystal Clear

ADVANCING QUANTITATIVE NEUTRON IMAGING AT LANSCE

High-fidelity neutron radiography is advancing materials characterization critical to national security and nuclear energy. Confidence in nuclear materials depends not only on knowing what they are made of, but how they behave under extreme conditions and over time. At the Los Alamos Neutron Science Center (LANSCE), one of only five pulsed neutron sources worldwide and the only one with access to special nuclear materials, scientists are developing new imaging capabilities to meet this need.

Instrument scientists Alex Long and Sven Vogel are leading the implementation of a new event-mode neutron imaging system that enables both spatially and temporally resolved measurements. This technology moves neutron radiography from a qualitative imaging tool to a quantitative method for mapping isotopic composition and microstructure.



(Left) Traditional, frame-based imaging records snapshots at fixed time intervals, capturing multiple neutron events. Because of the fixed time interval, the totality of each event is not captured, making the removal of gamma ray interactions and background light imprecise and resulting in a blurry image. (Center) Event-mode imaging records the full span of each neutron event individually (circled clusters). Because it picks up every photon (blue dots), it also picks up more background noise, resulting in an even lower-quality image. (Right) After event-centroiding and pulse-shape discrimination, background noise can be removed to reveal one precise location (yellow dot) for each neutron event. This results in a clear image with high spatial fidelity.

How Neutron Radiography Reveals Materials

Like x-ray imaging, neutron radiography forms images from transmitted radiation. However, neutrons interact with atomic nuclei rather than electron clouds. As a result, they are sensitive to light elements and isotope variations and can penetrate dense metals that block x-rays. This makes them uniquely suited for probing shielded components, fuel claddings, and complex nuclear systems.

At LANSCE, neutrons are produced by spallation: high-energy protons strike a tungsten target, releasing neutrons that travel along flight paths to experimental stations. Samples are placed in the beam, and transmitted neutrons are converted to visible light using a scintillator and recorded by a camera.

Because LANSCE is a pulsed source, scientists measure each neutron's time of flight– the travel time from source to detector– to determine its energy. This is essential because neutron interaction probabilities (cross sections) vary strongly with energy and differ for each isotope. Combining position and energy information enables energy-resolved imaging: each pixel contains a neutron attenuation curve across energy, forming a detailed material map.

Event-Mode Detection: Recording Every Neutron

Traditional neutron cameras are frame-based, integrating all detected light over a fixed exposure. This obscures the precise arrival time of individual neutrons and mixes neutron signals with gamma-ray background. In addition, light spreading within the scintillator blurs interaction locations.

Long and Vogel are using an event-mode camera called the LumaCam, which records each scintillation event independently with nanosecond timing. Instead of producing averaged frames, it generates a stream of timestamped, per-pixel events.

This enables two key processing techniques:

- Event centroiding, which reconstructs the exact neutron interaction position from the light distribution.
- Pulse-shape discrimination, which distinguishes neutron-induced photons from gamma-ray background based on timing characteristics.

Although event-mode systems generate very large data streams, advanced processing removes background and yields exceptionally clean radiographs—clean enough for quantitative analysis.

From Images to Quantitative Material Maps

Energy-resolved neutron imaging extracts physical information from attenuation curves.

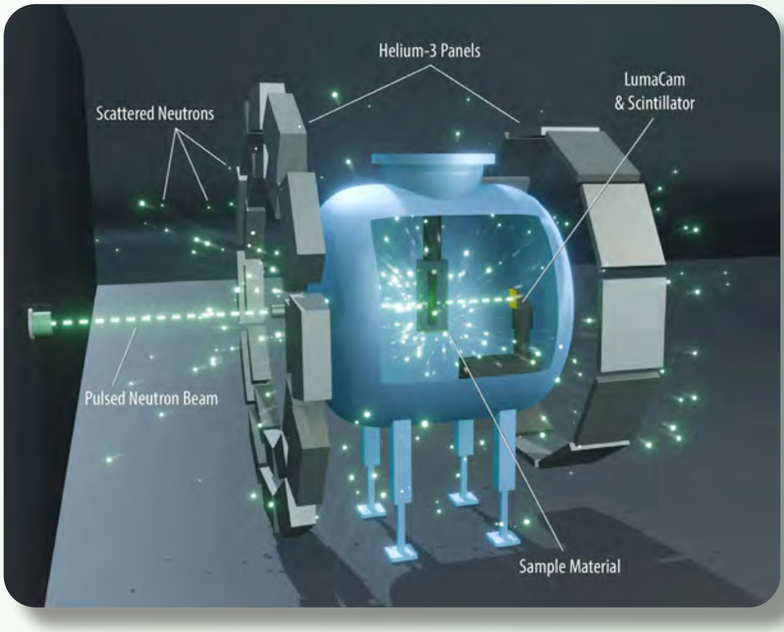
At higher energies, isotopes are identified through sharp absorption resonances—distinct peaks in attenuation unique to each isotope. At lower energies, interactions with crystal lattices produce step-like features known as Bragg edges, which provide information about crystal structure, phase distribution, and grain orientation.

By resolving these features at the pixel level, neutron images become quantitative maps of isotopic composition and microstructure. This capability is being applied to irradiated fuels and structural materials to validate performance and assess changes caused by extreme environments.

Imaging and Diffraction in a Single Experiment

Neutron diffraction provides highly sensitive information about microstructure but averages over the entire illuminated volume, losing spatial resolution. Imaging provides spatial maps but is less sensitive to subtle structural changes. Combining both techniques yields a more complete understanding.

Traditionally, imaging and diffraction required separate experiments. Using the LumaCam, Long and Vogel demonstrated simultaneous collection



The High-Pressure Preferred Orientation (HIPPO) diffractometer at LANSCE was retrofitted with a LumaCam event-mode camera to demonstrate simultaneous imaging and diffraction measurements. Neutrons are emitted from a source in pulses and travel along a flight path to the sample material, which is contained inside the HIPPO instrument. Neutrons transmitted through the material are detected by the LumaCam's scintillator for imaging, while scattered neutrons are detected by HIPPO's array of helium-3 panels for diffraction. Simultaneous collection of data for imaging and diffraction is cost and time efficient and reduces data uncertainly.

Los Alamos instrument scientists Alex Long (left) and Sven Vogel (right) install the LumaCam event-mode camera onto the High Pressure Preferred Orientation (HIPPO) diffraction flight path at the Lujan Neutron Scattering Center at LANSCE.

of transmitted and scattered neutrons by installing the camera downstream of the sample on the HIPPO time-of-flight diffractometer. This configuration enables spatially resolved imaging and sensitive bulk diffraction measurements in a single experiment, reducing beam time and improving data integration.

A Flexible Platform for Neutron Science

The LumaCam's modular, commercially available design makes it a promising alternative to traditional helium-3–based neutron detectors, which are costly and increasingly difficult to maintain. The same hardware can support imaging, diffraction, reflectometry, and small-angle scattering, with flexibility achieved through software processing.

By enabling precise time- and position-resolved detection of every neutron, event-mode imaging is redefining neutron radiography at LANSCE. The technique transforms imaging from a visual diagnostic into a quantitative tool capable of revealing what materials are made of and how they are structured—supporting the Laboratory's mission in nuclear energy and national security.

The work has roots in LDRD project 20230592ER led by Sven Vogel and Alex Long.

Read the full article by Maya Price and Alex Long here.

LDRD LONG-TERM IMPACT STORY

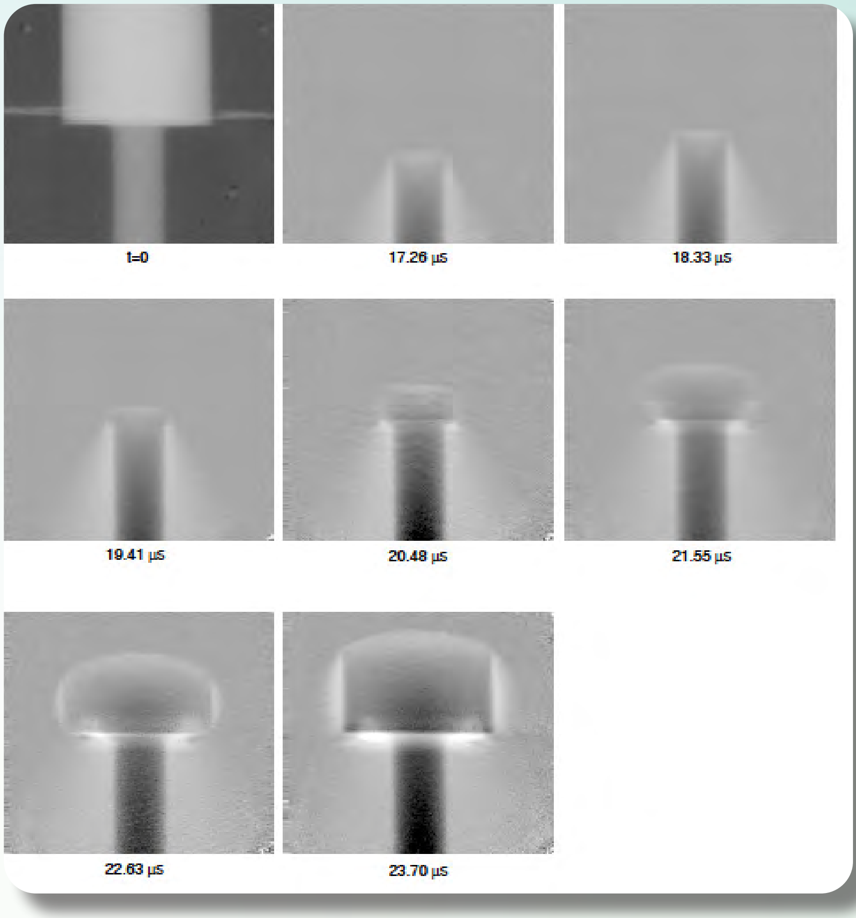
Proton Radiography at Los Alamos
FROM LDRD ORIGINS TO CUTTING EDGE CAPABILITY

In 1995, scientists at Los Alamos National Laboratory took a decisive step toward a new era of dynamic imaging. Researchers began developing a diagnostic capable of capturing materials in motion with unprecedented clarity. That technique– proton radiography (pRad)– has since evolved into one of the Laboratory's most powerful tools for understanding materials under extreme conditions.

Origins: A New Diagnostic for a New Era

*Proton radiography at Los Alamos originated from **two LDRD projects: High-Energy Test of Proton Radiography Concepts (1995)** and **Advanced Dynamic Radiography with Protons (1997)**, both led by LANL physicist **Chris Morris**. To build the first proton imaging device, Morris and his team repurposed a large quadrupole magnetic lens from a Los Alamos Neutron Science Center (LANSCE) cancer research beamline and used lower energy protons from the p3 beam line at the Los Alamos Meson Physics Facility (LAMPF). This first demonstration secured a small amount of funding for test using the primary beam from LAMPF with a lens constructed from vintage magnets from Lawrence Berkeley National Laboratory, and a high-speed camera.*

A proof-of-principle experiment at Brookhaven National Laboratory's Alternating Gradient Synchrotron strongly confirmed proton radiography's value as a new diagnostic. By using protons, positively charged particles with long mean free paths that penetrate dense materials, pRad enables scientists to capture the earliest moments of detonations. Leveraging the high-energy proton beam at LANSCE, pRad produces time-resolved images–scientific "movies"– of objects driven by high explosives, unlike traditional flash X-ray radiography.



Proton radiographs from work conducted during Morris' 1997 LDRD project show the time evolution of the burn front in detonating PBX-9502 high explosives. The radiographic times are displayed in the figure. The first frame is the "static" frame taken before the detonation. In subsequent frames, the swept-back shadow represents a high-density region created by the shock wave in the air that results from the detonation.

This capability became essential for the Lab's mission, revealing how materials deform, fail, or mix under extreme pressures and providing data critical for validating physics models and material certification and assessment.

Establishing pRad as a Workhorse

*Through continued LDRD support, Morris and his team were able to build on the work of the initial LDRD project to advance pRad development as a critical capability. In **2001**, their **LDRD***

Inside the pRad dome.

project Physics Issues in Proton Radiography developed and tested a permanent magnet (PMQ) x7 magnifier using 800-MeV protons, delivering impressive clarity for experiments involving fast-moving objects. By the early 2000s, pRad had matured into a full user facility at Los Alamos, capable of capturing events occurring in millionths of a second using advanced proton beams and high-speed cameras.

Momentum continued as LDRD-fund efforts pushed pRad into new scientific frontiers. In ***2011***, ***Amy Clarke*** led ***LDRD project, Developing Proton Radiography for Fundamental Solidification Experiments***, in which pRad was used for the first time to monitor in-situ solidification of metal alloys, resulting in a never-before-seen dynamic processes that occur during melting and solidification, advancing casting technology and materials understanding.

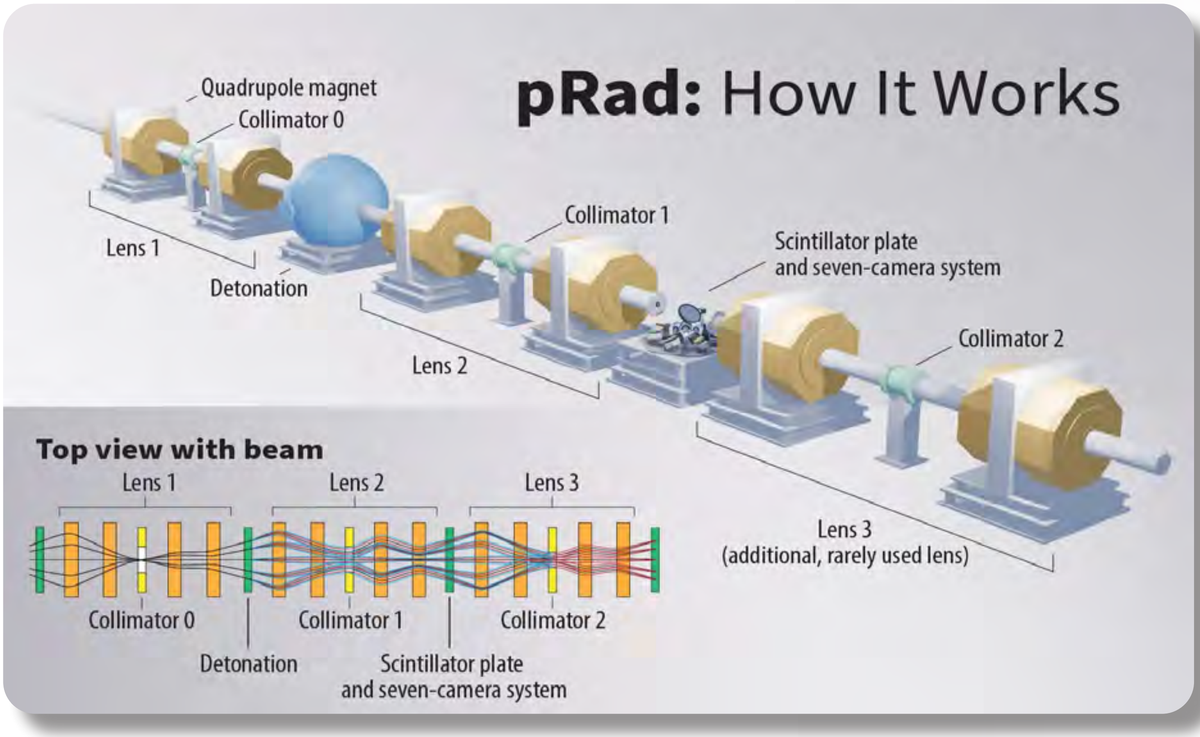
That same year, ***Alexander Saunders*** and ***Fesseha Mariam*** explored pRad's resolution limits through ***LDRD project Achieving the Ultimate Spatial and Density Resolution of 800 MeV Proton Radiography.*** This project helped to achieve a three-times greater magnification, with dramatically sharper image resolution. The results were transformative. Spatial resolution improved from roughly 200 micrometers to 50 micrometers, uncovering fine-scale details in material response that had previously been invisible. Once demonstrated, magnified pRad quickly became the standard configuration for a substantial number of experiments at LANSCE.

In ***2014 LDRD project Multi-GeV Electron Radiography*** led by ***Frank Merrill*** and ***Fesseha Mariam*** began designing a magnetic imaging system for high-resolution imaging with high-energy (multi-GeV) electrons. The project, which was deployed at Stanford's SLAC National Accelerator Laboratory, concluded with a demonstration that high energy electrons can also be used for the radiography of thin samples.

Expanding Capability– and New Challenges

As demand for high-resolution dynamic imaging grew, pRad's original magnification system faced challenges. Permanent magnets degraded under radiation exposure, requiring periodic

A view of pRad's tuned magnifier system taken from below. The blue sphere is the containment vessel where high explosives are used to drive various materials, and the silver cylinders house the quadrupoles that are positioned to guide the protons to form the images.



LANL's proton radiography experiment lets scientists see how materials behave during detonations. pRad starts when 300 million protons accelerated to near light speed trigger an explosion a kilometer away. The protons are focused by a magnetic lens before passing through a detonation inside a containment vessel. Some protons are deflected by the nuclear or Coulomb force and culled by a collimator. The protons that pass are refocused by an additional lens before striking a scintillator plate where their energy is converted to light that is photographed by seven high-speed cameras. The concentration of protons that hit the scintillator plate create the contrast between light and dark in the final images. Brighter spots indicate more protons and less dense materials; darker spots indicate fewer protons and denser materials. This image shows the path of protons in pRad. Note how magnets and collimators focus the beam both before and after the experiment. These steps select the protons that carry the most information about changing material densities and the physics of shockwaves.

disassembly and re-magnetization. In 2016, pRad transitioned to an electromagnet-based X3 magnification system. The new design eliminated radiation damage concerns while preserving the high-resolution capability that had become central to pRad's mission.

Full Circle: Plutonium Returns to pRad

Plutonium had last been dynamically imaged at pRad in 2007, using the original magnification system. Nearly two decades later, that capability has returned, stronger and more flexible than ever thanks, in part, to LDRD.

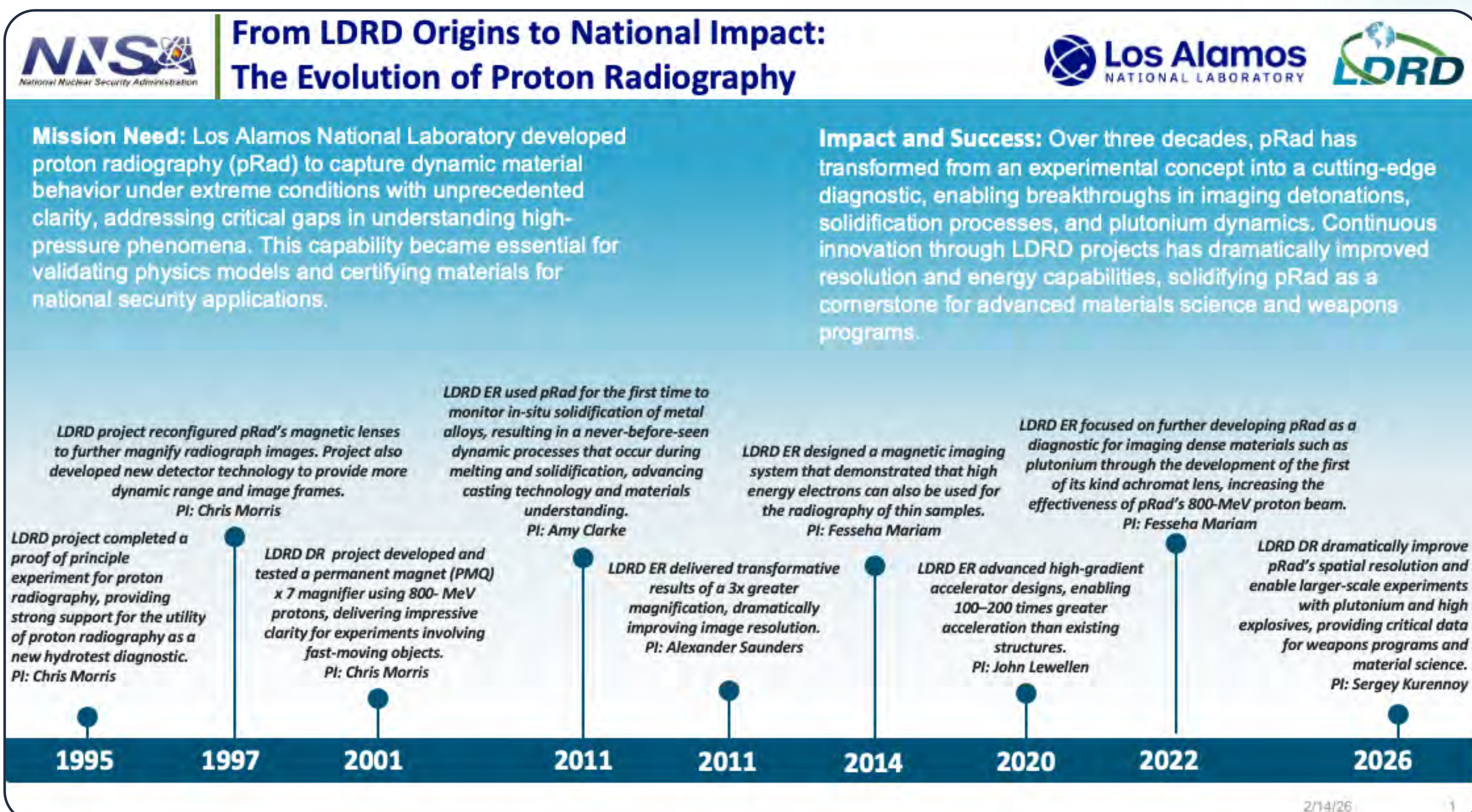
In ***2020****,* LANL researcher ***John Lewellen*** led ***LDRD project, Path to High-energy Proton Radiography Upgrade*** at LANSE that advanced *high-gradient accelerator designs, enabling 100–200 times greater acceleration than existing structures. This continuing research will pave the way for high-energy pRad at LANL that is more suitable for plutonium imaging.*

A 2022 LDRD project, High Depth-of-Field Proton Radiography, led by ***Fesseha Mariam*** and ***Matthew Freeman****, that was intended to further develop pRad as a diagnostic for imaging dense materials such as plutonium through the development of the first of its kind achromat lens, increased the effectiveness of pRad's 800-MeV proton beam.*

In September 2025, the pRad facility executed the first experiment, under a new Pu@pRad program, that marks the resumption of dynamic plutonium (Pu) imaging at LANSCE. The experiment represents the first step in the Pu@pRad capability. To further enhance capabilities needed for this new program, ***Sergey Kurennoy*** is leading work on ***LDRD project Enabling Multi-GeV Proton Radiography at LANSCE***, aiming to deliver proton beams at 3-5 GeV– nearly seven times the current 800-MeV energy. This energy increase will dramatically improve pRad's spatial resolution and enable larger-scale experiments, providing critical data for weapons programs and material science.

A Lasting Impact

From its inception in 1995 to today's cutting-edge plutonium experiments, proton radiography has evolved through innovation, persistence, and collaboration– driven by decades of LDRD investment.



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