SAND2025-03370R

RESEARCH

Laboratory Directed Research & Development

FY24 ANNUAL REPORT

"Any sufficiently advanced technology is indistinguishable from magic."

– Arthur C. Clarke

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

WHERE INNOVATION BEGINS

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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LABORATORY DIRECTED RESEARCH AND DEVELOPMENT

2024 ANNUAL REPORT

FROM THE CHIEF RESEARCH OFFICER

The U.S. Department of Energy (DOE) formally authorizes the LDRD program "to maintain the scientific and technical vitality of the laboratories; to enhance the laboratories' ability to address current and future DOE/NNSA missions; to foster creativity and stimulate exploration of forefront areas of science and technology; to serve as a proving ground for new concepts in research and development; and to support high-risk, potentially high-value research and development." What an exciting opportunity and challenge! As Sandia National Laboratories Chief Research Officer, I am responsible for executing a successful and high-return LDRD program, and I'm proud to say that our program is a strategic mechanism that leverages innovation to solve problems of critical importance.

In our rapidly evolving world, we must be able to respond quickly to national security challenges. Our "Mission Agility" projects have more advanced technical readiness levels, meaning the outcomes could impact the mission sooner via applied and deployed tools and technologies. Our "Technical Vitality" projects are groundbreaking and expected to lead to a new capability a bit farther down the road.

In terms of "Workforce Development," researchers clamor to come to Sandia to work because of our outstanding tools and facilities, and they often continue working here for many years or their whole career because their skills are sharpened as they collaborate with other experts on crucial multi-disciplinary projects. From university students and postdoctoral fellows to experienced scientists and engineers—we have thousands of R&D professionals pursuing amazing opportunities as they support their careers and NNSA priorities at Sandia.

As you read about this year's exciting projects, you will note how many of them leverage new talent while achieving great things, such as:

- Confirming that the travel time of photons can be reliably predicted.
- Using Sandia's Z machine as a possible seismic source to detect nuclear tests.
- Revolutionizing the size and power efficiency in resonator technology for critical missions.
- Breaking legacy radio frequency (RF) sensing limits, which is crucial for GPS-denied environments, secure communications, and both offensive and defensive RF countermeasures.
- Designing a novel sensor head that is a tenfold improvement over existing technology.

I am proud of all the incredible achievements Sandia's LDRD program helps to facilitate, and it's my privilege to support those who work here in service to our nation.

Douglas B. Kothe

CONTENTS

LDRD PROGRAM OVERVIEW

Sandia is a federally funded research and development center (FFRDC) focused on developing and applying advanced science and engineering capabilities to mitigate national security threats. This is accomplished through the exceptional staff leading research at the Labs and partnering with universities and companies.

Sandia's LDRD program aims to maintain the scientific and technical vitality of the Labs and to enhance the Labs' ability to address future national security needs. The program funds foundational, leading-edge discretionary research projects that cultivate and utilize core science, technology, and engineering (ST&E) capabilities. Per Congressional intent (P.L. 101-510) and Department of Energy (DOE) guidance (DOE Order 413.2C, Chg 1), Sandia's LDRD program is crucial to maintaining the nation's scientific and technical vitality.

LDRD PROGRAM OBJECTIVES

Sandia's LDRD objectives guide the program overall and align with DOE Order 413.2C and National Nuclear Security Administration (NNSA) guidance. The Mission Agility and Technical Vitality Objectives are supported by the Workforce Development Objective, which is a critical element to affect, grow and leverage the technical experts needed to execute R&D projects.

SANDIA'S LDRD PROGRAM STRUCTURE

Sandia's LDRD investments are structured around three Program Areas, which are further broken down into Investment Areas (IA). Each IA is focused on discipline- or mission-based research priorities set by Sandia's leadership. The LDRD program structure and the allocation of funds to the associated IAs are designed to align LDRD investments with Sandia strategy and future national security mission needs.

LDRD INVESTMENT AREA ROLES

Research Foundations: Research Foundations steward discipline-based science, technology, and engineering competencies that address the extensive national security challenges within Sandia's mission space. Each of the Research Foundations focuses on stewarding differentiating or unique capabilities in seven areas.

LDRD Investment Area Roles

RESEARCH FOUNDATIONS

Research Foundations (RF) steward discipline-based ST&E competencies that address the extensive national security challenges within Sandia's mission space. Each of the RFs focuses on stewarding differentiating or unique capabilities in seven areas.

MISSION FOUNDATIONS

Sandia oversees five major portfolios that address national security mission challenges. LDRD Mission Foundations align with the portfolios and conduct the applied research needed to develop capabilities and demonstrate solutions.

STRATEGIC INITIATIVES

Strategic Initiatives (SI) promote strategic collaborations and CRO/Labs-directed

initiatives. SI include Grand Challenge projects to solve major research challenges that require large multidisciplinary teams; Mission Campaign IAs to move ST&E intentionally from idea to mission impact; Exploratory Express to execute short-term projects of strategic importance; and New Ideas to pioneer fundamental R&D to discover game-changing breakthroughs. These initiatives also support strategic academic collaborations (133 in FY2024) and both the Harry S. Truman and Jill Hruby Postdoctoral Distinguished Fellowships.

LDRD PROGRAM VALUE

Performance Indicators

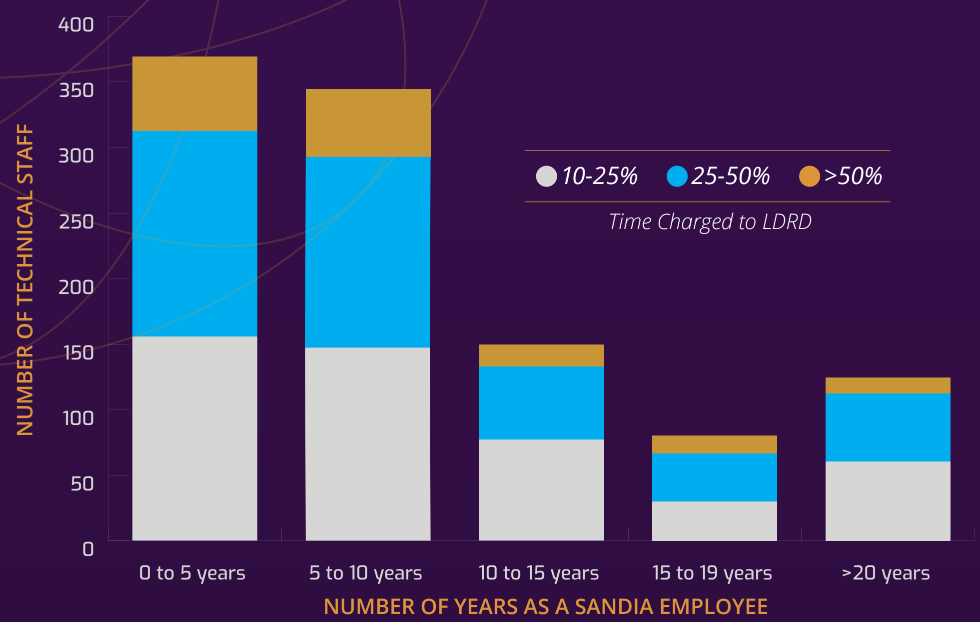
While the FY2024 LDRD program represented only about 5.0% of Sandia's total costs, the metrics shown below highlight how LDRD has a much greater relative impact on key performance indicators (KPI) and metrics for the Labs. The bar graph illustrates the large percentage of early career staff engaging on LDRD projects, thus validating LDRD's important role in attracting, developing, and retaining a world-class workforce to meet our most challenging national security needs.

$257.4M
Total Program Cost
(not including PM costs)

$406K
Median Project Size

572
Total LDRD Projects

308
New Projects in 2024



54% OF SANDIA TOTAL
248
LDRD-Supported Postdocs

60% OF SANDIA TOTAL
18
LDRD-Supported Postdoc to Staff Conversions

30% OF SANDIA TOTAL
391
Refereed Publications

44% OF SANDIA TOTAL
120
Technical Advances

50% OF SANDIA TOTAL
57
Patents Issued

27% OF SANDIA TOTAL
45
Copyrights

50% OF SANDIA TOTAL
1
R&D 100 Awards

LONG-TERM METRICS

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 are updated annually. As expected, the data may vary from year to year so long-term running totals will be included and updated every 5 years.

BACKGROUND

Applying continuous improvement, representatives from each LDRD program at the NNSA laboratories (Sandia, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory) regularly participate in a working group to share best practices and discuss strategies for tracking the long-term impact of LDRD investments. The working group finalized a combination of common quantitative and qualitative long-term indicators, emphasizing a systematic approach to be utilized by each NNSA LDRD laboratory, and acknowledged that individual laboratories may choose to report other long-term indicators that fit their unique missions and capabilities.

ALIGNMENT WITH LDRD OBJECTIVES

The KPI for LDRD, including numerical KPIs in the form of metrics and qualitative KPIs in the form of project highlights, illustrates the long-term payoffs/success of the program in meeting its three objectives: Mission Agility, Technical Vitality, and Workforce Development. Because KPIs crosscut the three objectives, this report will not provide a 1:1 mapping.

IMPORTANCE OF QUALITATIVE DATA

Developing numerical indicators for R&D program success is widely recognized as difficult. The NNSA LDRD metrics working group developed numerical success indicators for both Technical Vitality and Workforce Development. Project highlights or "success stories" capture the successes in Mission Agility and some aspects of the other two LDRD objectives not well represented by numerical metrics.

TRACING IMPACT BACK TO LDRD

Throughout this section, you will see references to "LDRD roots." LDRD mentors and principal investigators (PI) often discuss what it means for an accomplishment to have LDRD roots. A simple case might involve an idea for an invention that 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 quickly. 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 a current LDRD project relies on an earlier LDRD accomplishment, then it is considered to have "roots" in the prior LDRD project. Other relevant definitions for metrics are included in the sections to follow.

ROOTED IN LDRD

THE INDICATORS

Top 2%

A relevant indicator of career advancement in an ST&E field is the recognition of individuals as distinguished members of the technical staff, known as Senior Scientists/Engineers and Fellows at Sandia, Fellows at Los Alamos National Laboratory, and Distinguished Members of the Technical Staff at Lawrence Livermore National Laboratory.

The shorthand name used here, "Top 2%," comes from the intent at each laboratory to limit membership to the top 1% or 2% of scientific and technical staff. Typically nominated and screened by a committee, the Top 2% are recognized for something similar to a lifetime achievement, in this case, for contribution to the mission of each laboratory.

Each year at Sandia, a small number of staff are appointed to the rank of Senior Scientist/Engineer, an honor based on exceptional leadership and consistently outstanding contributions to Sandia's national security missions. In FY24, 10 out of the 14 staff promoted to Senior Scientist/Engineer were involved in the LDRD program as a PI or team member during their careers. Since FY11, 75% of Sandia's Senior Scientists Engineers have careers with LDRD roots.

Sandia also reserves a special recognition for an elite group of individuals—Sandia Fellows— recognized for careers of significant accomplishment for the Labs and for the nation. In Sandia's history, only 21 individuals have held this title (19 individuals with R&D careers and 2 individuals in non-technical positions). In FY24, nine of the R&D Fellows were on staff, and all have been involved with LDRD in their careers. The LDRD Program's Strategic Partnerships pillar funds a set of projects selected and managed by Sandia Fellows. The Fellow projects enable the Labs' most stellar R&D staff to mentor promising staff as they pursue leading-edge, potentially high-impact R&D. In FY24, there were 35 active Fellows projects across ten IAs. (Read about two Fellow projects: Breaking legacy radio frequency sensing limits and Understanding and designing pathways through materials critical to energy storage.)

LDRD AND TOP 2% TECHNICAL STAFF AT SANDIA NATIONAL LABORATORIES

	SINGLE YEARS			FIVE YEARS		TO DATE*
	FY22	FY23	FY24	FY11-15	FY16-20	FY11-24
TOTAL AWARDS	15	26	14	26	53	130
AWARDS WITH LDRD ROOTS	13	21	10	15	44	98
PERCENTAGE WITH LDRD ROOTS	86%	80%	71%	57%	83%	75%
AVERAGE YEARS FROM FIRST LDRD EXPERIENCE	19.5	19	17.4	9.9	17.8	14.9

**Initial year to date: Each laboratory has chosen the appropriate lookback period that will ensure data integrity.*

BOYCE

"The LDRD program has helped me seed new research ideas, hone my proposal skills, contribute to cutting-edge research, and serve as a mentor and leader. Many of my most creative and successful ideas have stemmed from LDRD brainstorming...it is a tremendous resource for Sandia researchers such as myself to have the time and funding needed to facilitate breakthroughs."

– Brad Boyce

HART

William Hart is a leading researcher in optimization and computational science, whose work within the LDRD program has led to significant advancements in algorithm development and high performance computing. His research focuses on creating innovative optimization techniques and leveraging machine learning and artificial intelligence to solve large-scale, complex problems in energy systems, national security, and advanced manufacturing. Hart's contributions have enhanced the efficiency of high performance computing systems, accelerating scientific discovery and technological innovation across diverse fields such as biology, chemistry, and physics. His interdisciplinary collaborations and cutting-edge methodologies continue to drive progress in various scientific and engineering disciplines.

Brad Boyce is a renowned materials scientist whose work within the LDRD program has significantly advanced understanding of materials under extreme conditions. His research into the behavior of materials under high strain rates, temperatures, and corrosive environments allows him to help develop high-performance materials for critical applications in aerospace, defense, and energy sectors. Utilizing advanced characterization techniques, Boyce's contributions have led to the evolution of new materials and technologies, addressing key national security and technological challenges. He has a broad publication record with topics that include aspects of elasticity, strength of materials, plasticity, fatigue, creep, and fracture on materials ranging from steels to silicon to corneal tissue.

CHOU

Domain Chief Engineer **Stanley Chou** specializes in microelectronics integration and packaging within the Microsystems Engineering, Science and Applications (MESA) center and excels in designing, integrating, and scaling up integrated electronics and materials for challenging environments. He oversees all electronics packaging and integration activities at MESA, utilizing his strong leadership skills and proficiency in advanced analytical techniques and software tools. His extensive skill set includes leadership development, nanotechnology, experimentation, powder X-ray diffraction, microscopy, and materials science. His early career as postdoc at Sandia involved pioneering work with colloidal 2D materials, resulting in notable scientific publications and successful research proposals. Chou's contributions through his LDRD projects have been instrumental in advancing the field of materials science and enhancing Sandia's capabilities.

STICK

"The LDRD program funded the first ion trap fabrication project at Sandia in 2005. That effort introduced me to the Labs as a graduate student and served as the seed for what would become two decades of primarily externally funded projects in which Sandia demonstrated the scalability of microfabricated surface traps, became a national foundry for ion traps, and...grew into an entire department focused on trapped ion quantum research. Other LDRDs since then have supported high risk trapped-ion research, helping Sandia remain a leader in this rapidly evolving field."

– Dan Stick

McCORMIC

Rick McCormick has dedicated his career to the design and development of novel optical microsystem products, incorporating microoptics, array optoelectronics, and high-speed digital and RF electronics. He joined Sandia in mid-2003, helping lead projects that integrate advanced optical technologies into national security products and

Dan Stick is a pioneering physicist whose work within the LDRD program has significantly advanced quantum information science and technology. Focusing on the development and manipulation of trapped ion systems, Stick's research aims to enhance the coherence times, gate fidelities, and scalability of quantum bits (qubits), which are essential for building practical quantum computers. Additionally, his exploration of quantum communication technologies, including quantum key distribution, endeavors to integrate secure quantum networks with existing classical infrastructure. Stick's contributions have the potential to revolutionize computing, communication, and information security, addressing some of the most challenging problems in modern science and technology.

CK

explored innovative applications of optical microelectromechanical systems, photonic crystals, silicon photonics, biophotonic sensors, and optical signature control. He has over 80 publications and 16 patents and patents pending. At Sandia, McCormick was the PI for two LDRD projects and helps to lead the Nanodevices and Microsystems LDRD Investment Area.

Another 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 national labs/sites often partner with sister organizations, such as the Intellectual Property Office and Public Affairs, to track whether R&D 100 winners in either the standard category or special awards have "LDRD roots." Often, because of the long development time from an LDRD idea to practical implementation, the staff who work on an award-winning technology product may not be the same researchers who initiated 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.

Since 1976, Sandia has won 152 awards, illustrating the Labs' contributions in developing products and technologies with the potential to change industries and make the world a better place. Over the past three years, 57% of Sandia's R&D 100 winning contributions have been rooted in LDRD; over the past 19 years, 69% have come from LDRD.

LDRD and R&D 100 Awards Awarded to Sandia National Laboratories

Counts include standard R&D 100 awards and special recognition awards, as well as awards led by other organizations where Sandia was a key partner.

	SINGLE YEARS			FIVE YEARS		TO DATE*
	FY22	FY23	FY24	FY11-15	FY16-20	FY06-23
TOTAL AWARDS	6	6	2	20	32	94
AWARDS WITH LDRD ROOTS	3	4	1	15	22	65
PERCENTAGE WITH LDRD ROOTS	50%	67%	50%	75%	69%	69%
AVERAGE YEARS FROM FIRST LDRD EXPERIENCE	4.3	12.5	2	5	5.6	5.4

**Initial year to date: Each NNSA laboratory has chosen the appropriate lookback period that will ensure data integrity.*

JILL HRUBY

From Sandia LDRD researcher to R&D 100 Award winner to Sandia Labs Director to NNSA Administrator

During her 34-year career at Sandia and afterward, **Jill Hruby** had a great impact. She acted as the LDRD PI on the LIGA Micromachining project at Sandia in 1997-1998, which led to the development of a micromachining technology using high energy x-rays from synchrotrons to create patterns with small lateral dimensions in a deep, non-conducting polymeric resist.

Jill Hruby, former Sandia Labs Director, Under Secretary for Nuclear Security and NNSA Administrator (Photo by Nuclear Threat Initiative, Greg Gibson)

In 1999, Hruby's team, in partnership with industry, won an R&D 100 Award for developing solid-state radiation detectors. Their approach used an improved technique to grow detector-grade CZT crystals and created a new method for reducing the dark current flowing along the crystal surfaces which allowed for major improvements in the signal-to-noise ratio, long-term stability, and yield of single-crystal material.

The radiation detectors, which could make accurate measurements operating at room temperature, had diverse uses including X-ray radiography, environmental cleanup, nuclear materials safeguarding, treaty verification, and tumor detection.

Richard Olsen and Eilene Cross hold the Sandia R&D 100 Award winner, solid state radiation detectors. (Photo by Linda Hadley)

Before rising to become the first woman to lead any of the three DOE/NNSA national security labs, Hruby served as Sandia's vice president of Energy, Nonproliferation, and High-Consequence Security Division; leader of Sandia's International, Homeland, and Nuclear Security Program; and held several leadership positions in materials science, weapon components, and micro-technologies.

Since her retirement from Sandia in 2017, Hruby served as a Distinguished Fellow and the inaugural Sam Nunn Distinguished Fellow at the Nuclear Threat Initiative from 2018-2021. She was sworn in as the Under Secretary for Nuclear Security of the U.S. Department of Energy, and Administrator of the National Nuclear Security Administration in 2021.

PROFESSIONAL FELLOWS

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 affiliated laboratory. Researchers at Sandia have been elected as fellows to over 25 prestigious scientific and engineering societies, with the most fellows elected to the societies listed below.

- American Association for the Advancement of Science
- American Institute of Aeronautics and Astronautics
- American Physical Society
- American Society of Mechanical Engineers
- Institute of Electrical and Electronics Engineers
- National Academy of Engineering
- Society for Industrial and Applied Mathematics

	SINGLE YEARS			FIVE YEARS		TO DATE*
	FY22	FY23	FY24	FY11-15	FY16-20	FY06-24
TOTAL AWARDS	4	8	7	40	41	107
AWARDS WITH LDRD ROOTS	4	8	6	31	35	88
PERCENTAGE WITH LDRD ROOTS	100%	100%	85%	77%	85%	82%
AVERAGE YEARS FROM FIRST LDRD EXPERIENCE	17	18.5	14.5	12.3	14.4	14.2

**Initial year to date: Each laboratory has chosen the appropriate lookback period that will ensure data integrity.*

Fellowship Awards

Read about individuals at Sandia who have been elected fellows of professional societies in the Workforce Development section of this Annual Report.

SHORT-TERM METRICS

Intellectual Property

PATENTS

Number of U.S. and foreign patents issued in a given FY.

	FY20	FY21	FY22	FY23	FY24
SANDIA PATENTS	131	120	92	114	114
LDRD SUPPORTED	67	63	40	43	57
% DUE TO LDRD	51%	53%	43%	44%	50%

LDRD supported: Patents issued that would not exist if not for initial work funded by LDRD.

COPYRIGHTS

Number of copyrights created in a given FY.

	FY20	FY21	FY22	FY23	FY24
SANDIA COPYRIGHTS	151	170	146	135	169
LDRD SUPPORTED	40	34	26	23	45
% DUE TO LDRD	26%	20%	18%	17%	27%

LDRD supported: Copyrights issued that would not exist if not for initial work funded by LDRD.

INVENTION DISCLOSURES

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

	FY20	FY21	FY22	FY23	FY24
SANDIA DISCLOSURES	299	295	280	277	274
LDRD SUPPORTED	111	128	117	120	120
% DUE TO LDRD	37%	40%	42%	43%	44%

LDRD supported: Disclosures issued that would not exist if not for initial work funded by LDRD.

SHORT-TERM METRICS

Peer-reviewed Publications

PUBLICATIONS

Number of peer-reviewed publications, as a function of publication year.

	FY20	FY21	FY22	FY23	FY24
SANDIA PUBLICATIONS	1299	1493	1456	1372	1291
LDRD SUPPORTED	343	379	380	408	391
% DUE TO LDRD	26%	25%	26%	30%	30%

LDRD supported: Publications that would not exist if not for initial work funded by LDRD.

Science and Engineering Talent Pipeline

STUDENT INTERNS SUPPORTED BY LDRD (>10%) AT SANDIA

Number of graduate and undergraduate students working full- or part-time for the Labs, who charged at least 10% time to LDRD.

	FY20	FY21	FY22	FY23	FY24
GRAD STUDENTS	127	139	147	158	187
UNDERGRAD STUDENTS	100	84	110	118	129
SANDIA R&D STUDENTS	722	711	841	857	933
% DUE TO LDRD	31%	31%	31%	32%	34%

POSTDOCTORAL RESEARCHER SUPPORT

Number of postdoctoral researchers working full- or part-time for the Labs.

	FY20	FY21	FY22	FY23	FY24
SANDIA POSTDOCS	350	428	459	453	459
LDRD SUPPORTED >10%	163	196	209	231	248
% DUE TO LDRD	46%	46%	46%	51%	54%

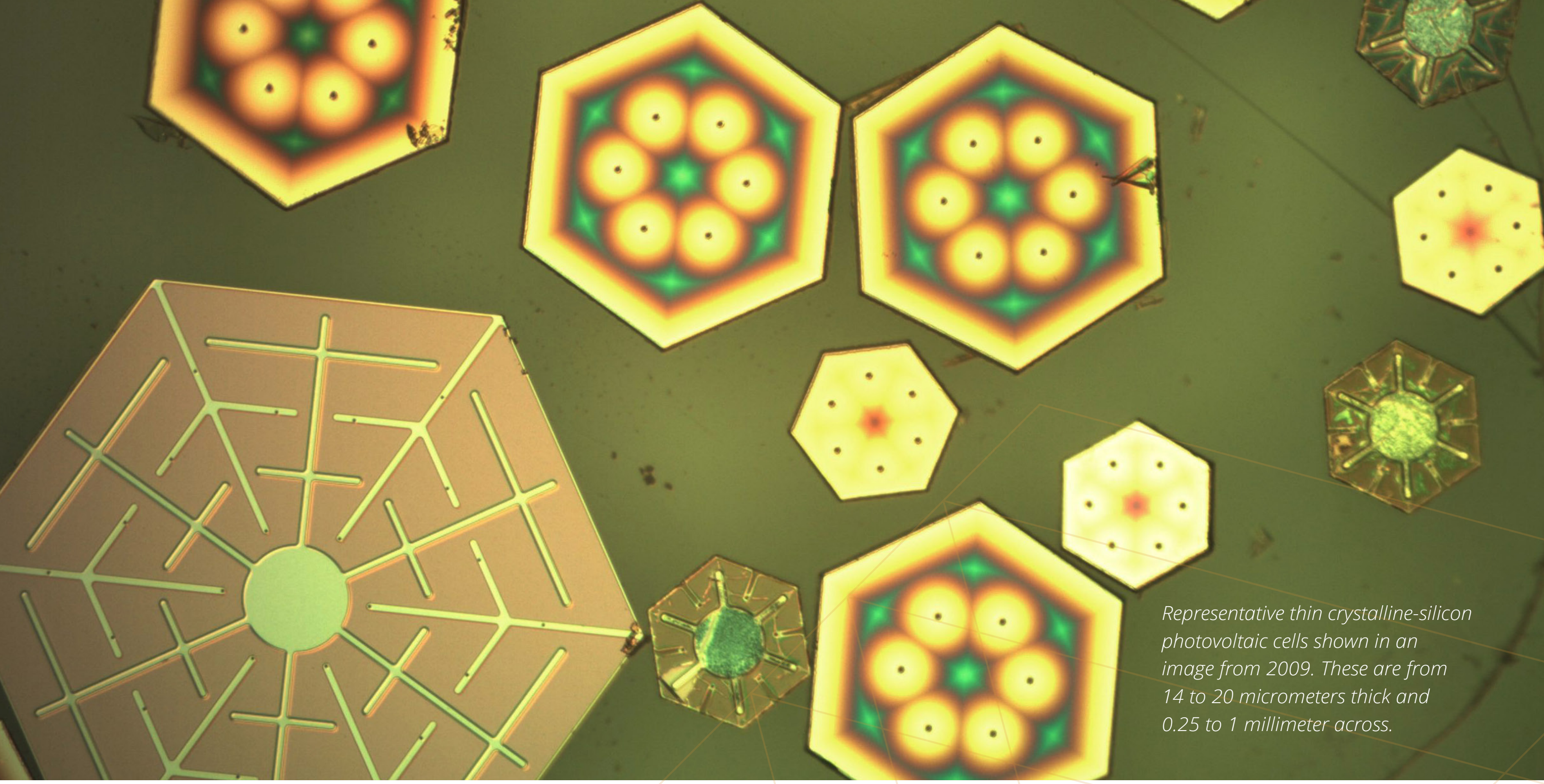
LDRD supported: Postdoctoral researchers charging at least 10% time to LDRD.

POSTDOCTORAL RESEARCHER CONVERSIONS

Number of conversions from postdoctoral researcher to a member of the staff.

	FY20	FY21	FY22	FY23	FY24
SANDIA CONVERSIONS	47	61	94	85	30
LDRD SUPPORTED >10%	25	32	42	54	18
% DUE TO LDRD	53%	52%	45%	64%	60%

LDRD supported: Conversion of postdoctoral researchers who charged at least 10% time to LDRD in the fiscal year preceding the conversion.



Representative thin crystalline-silicon photovoltaic cells shown in an image from 2009. These are from 14 to 20 micrometers thick and 0.25 to 1 millimeter across.

LDRD IMPACT STORY

Bringing energy to broad applications through microsystems-enabled photovoltaics

LDRD helps create "solar glitter"

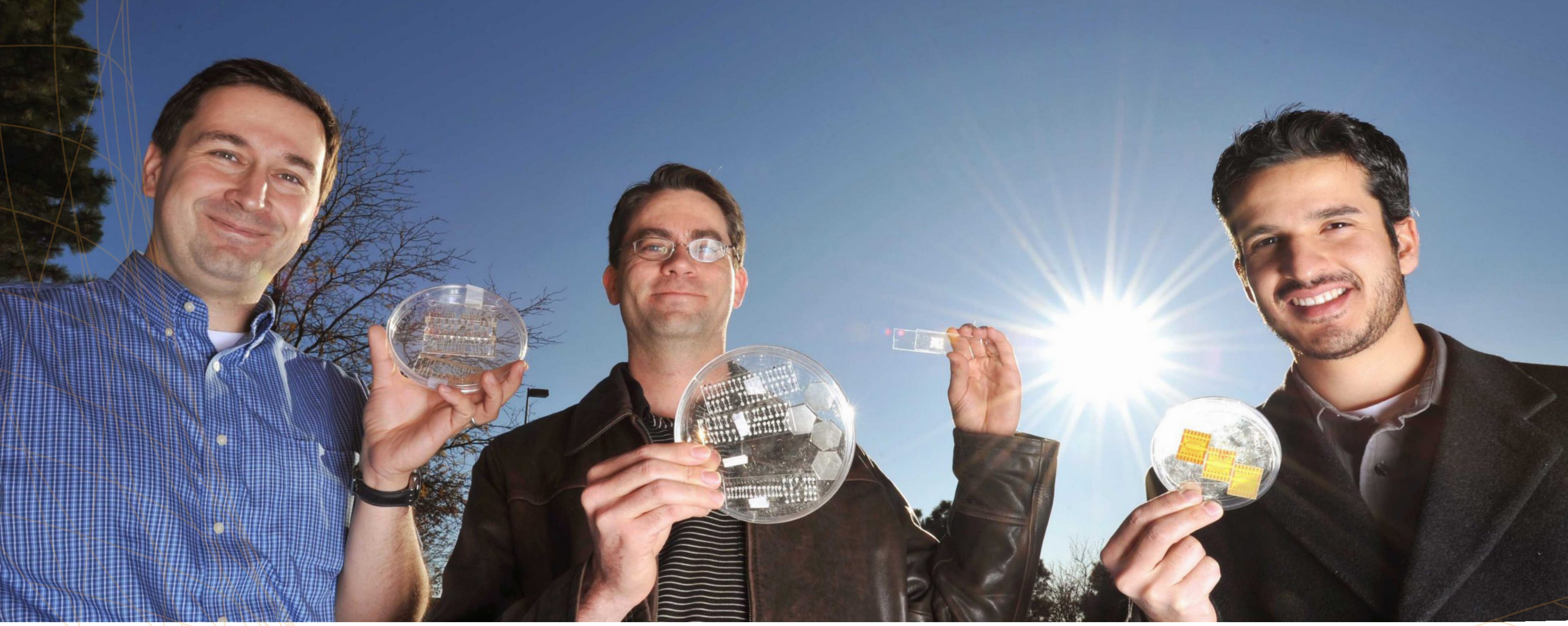
Back in 2008, Sandia and the National Renewable Energy Laboratory created a remarkable photovoltaic (PV) technology that could generate power anywhere there was light. Seeing the possibilities, Sandia LDRD researchers in 2010 took the technology and developed microsystems-enabled photovoltaics (MEPV). These miniature flexible solar panels were known as "*solar glitter*" due to their size and sparkle. MEPV could fit almost anywhere and offered a new, efficient, and inexpensive way to generate electricity simply by exposing devices to light.

Developing the capability

In 2012, the Microsystems-Enabled Photovoltaics (MEPV) Grand Challenge was selected for funding. The proposal outlined a high-risk, high-reward multi-disciplinary path toward a next-generation PV module and system based on MEPV technology that could provide innovative solutions for portable solar power.

The LDRD-developed MEPV technology employed microdesign and microfabrication techniques to produce solar cells, which were printed onto low-cost substrates with embedded contacts and microlenses to focus sunlight. To construct them, researchers used tools from microelectromechanical systems, liquid crystal devices, light-emitting diodes, and PV.

The return on the $13.6 million LDRD investment was substantial, delivering a 10x improvement in performance, increased flexibility, and decreased cost, all while maintaining robustness against damage. The MEPV capability was so outstanding, it was recognized with an R&D 100 award in 2012.



From left to right, researchers Murat Okandan, Greg Nielson, and Jose Luis Cruz-Campa, hold samples containing arrays of microsolar cells from 2009, when the MEPV technology was just getting off the ground.

Global interest

The introduction of micron-sized solar particles that absorb sunlight on one side and generate electrical energy on the other sparked global interest.

The capability was pursued through the Advanced Research Projects Agency-Energy (ARPA-E) MOSAIC project in 2014. This effort leveraged expertise in conventional flat-plate PV, CPV, manufacturing, optical engineering, and materials science to produce a new class of PV panels. These could be deployed across a wide range of geographical locations and reduce dependence on imported energy.

Through the years, the MEPV technology continued development through a variety of enterprise-wide, commercial mechanisms, and university collaborations. This collaborative approach led to the generation of a substantial intellectual property portfolio, with 46 patents awarded related to MEPV technology.

This includes licensing by the Sandia Grand Challenge co-PI Murat Okandan who turned-entrepreneur in 2017 through Sandia's Entrepreneurial Separation to Technology Transfer (ESTT) program. Murat started mPower Technology and was awarded $1.1M through the Army's Small Business Innovation Research program, which aligns innovative small businesses with critical U.S. Army priorities. This led to receipt of a $16.2M venture investment to further mature the technology and ultimately resulted in a 2021 ESTT Award from the Federal Laboratory Consortium.

LDRD investments helped enable the capability

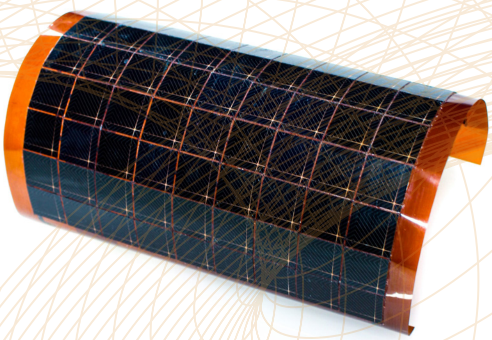
MEPV represents a transformative advancement in solar technology, and significant early LDRD investments helped to grow the MEPV capability significantly.

As commercialization efforts continue and new applications emerge, MEPV is poised to make a lasting impact on any applications that could use the sun for power.

To space and beyond

MEPV's lightweight and flexible design has been used in a myriad of diverse applications. For instance, the integration of solar cells into military camouflage tents demonstrates the technology's versatility and potential for real-world impact. This adaptability has made MEPV particularly appealing for sectors such as aerospace, where efficient energy sources are crucial.

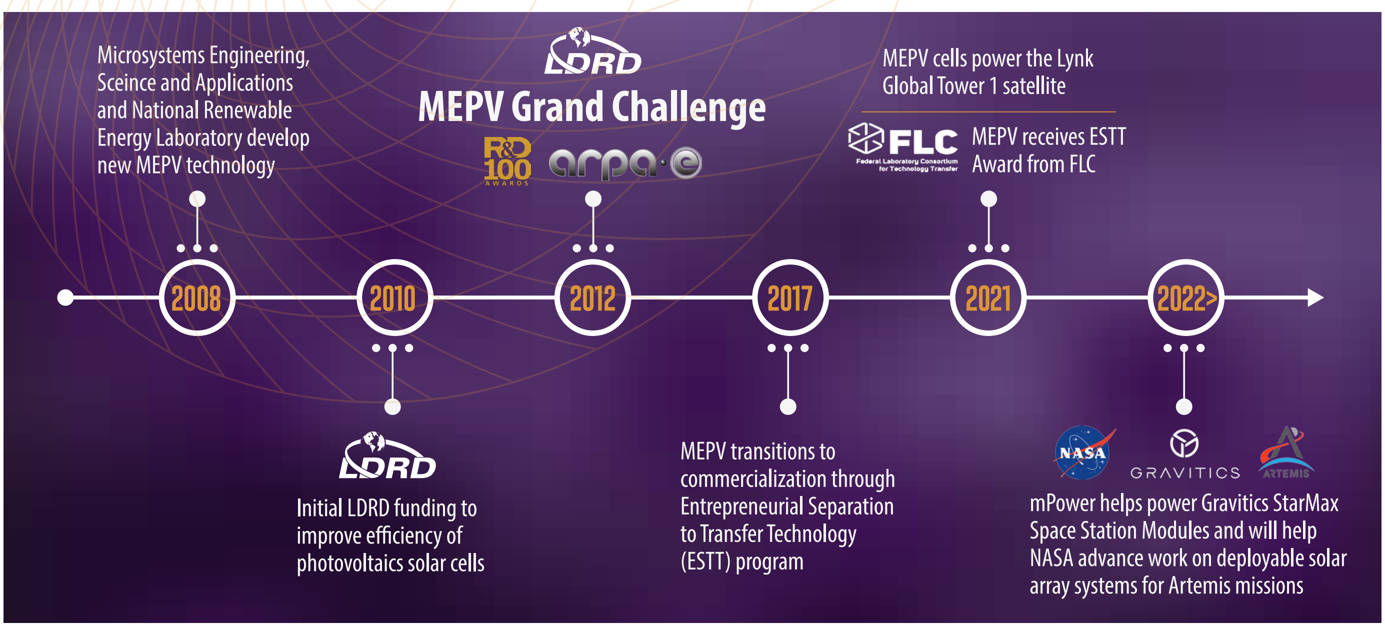
Through mPower Technology's commercialization of the MEPV technology, Lynk Global and Gravitics use MEPV technology for solar modules for satellites and space habitat. The Lynk Global Tower 1 satellite was the first commercial cell tower in space, exemplifying the technology's capability to operate in extreme environments, such as space power systems.



This photo shows what DragonSCALES look like today. Formerly known as solar glitter when initially developed at Sandia, the technology has evolved since being transferred to mPower Technology.

mPower's collaboration with OneWeb to test DragonSCALES™ (Semiconductor Active Layer Embedded Solar) on new satellites highlights the growing interest in integrating MEPV technology into global communication networks. And as demand for high-speed internet and connectivity increases, MEPV's lightweight and efficient solar solutions could play a crucial role in expanding access to remote areas. mPower and spacecraft systems company Honeybee Robotics Inc. were recently selected by NASA as one of five commercial teams to develop designs for deployable solar array systems to be used on the surface of the moon and one day as charging stations to recharge rovers, battery packs, and other electrical equipment used by spacecraft and astronauts.

Vipin Gupta, another core member of the original MEPV team, is actively marketing MEPV patents to facilitate rapid deployment in various sectors. Gupta envisions MEPV technology powering everyday household items, such as flat-screen televisions, thereby integrating renewable energy solutions into daily life.



PROJECT HIGHLIGHTS –

MISSION AGILITY

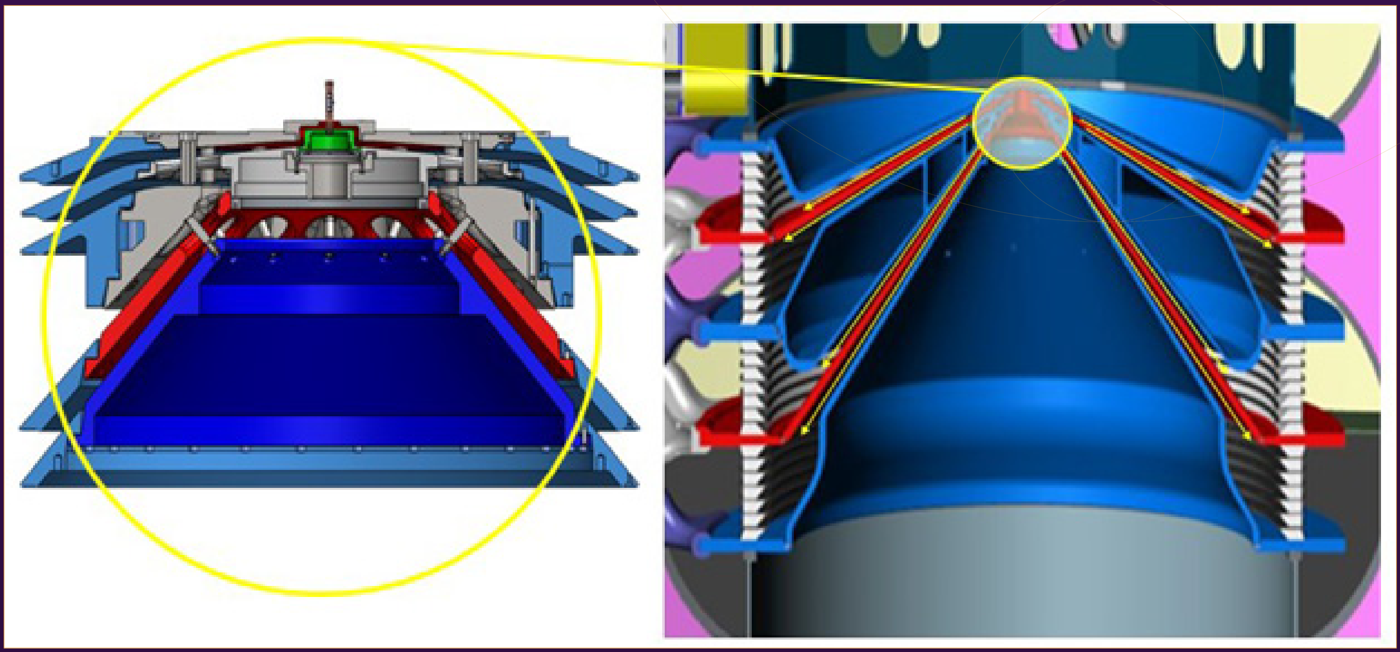
Sandia's LDRD program is organized around three themes: mission agility, technical vitality, and workforce development. Mission agility and technical vitality are closely related but differentiated by the technical readiness levels (TRL) of the research outcomes. The research outcomes in this section have a higher TRL and could impact Sandia's mission work more quickly.

Developing next-generation containment systems

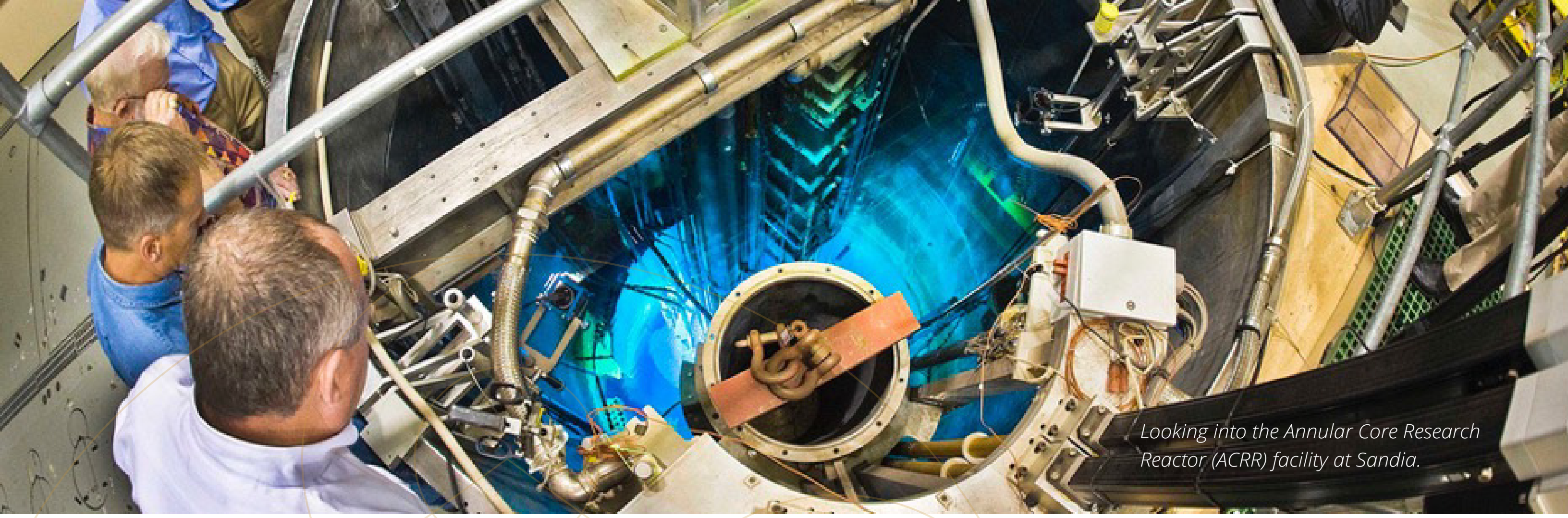
Sandia researchers are addressing a critical challenge at the Z facility, where the energy deposition and high temperatures from 20 MA shorting at the target create an instantaneous plasma that generates a rapidly expanding debris field. This debris, consisting of gas, solid, and liquid states, can damage essential components, leading to extensive refurbishment and unplanned shutdowns for repairs.

To mitigate this issue, Sandia is proposing an active method to close the final feed gap in the upper anode and cathode region. This innovative approach will reduce debris, limit waste to just the upper two convolutes, with a focus on developing next-generation containment systems that require low inductance, fast-acting closures capable of meeting future scientific needs.

Sandia researchers are committed to advancing this technology for enhanced reliability and performance in mission-critical applications. A scheduled Z shot will demonstrate the effectiveness of this design in preventing debris and achieving explosive welds, and the findings will contribute to future upgrades in pulsed power systems. (PI: Pete Wakeland)



The Z Insulator Stack, magnetically insulated transmission line, and disposable convolute (circled).



Looking into the Annular Core Research Reactor (ACRR) facility at Sandia.

Leveraging machine learning to refine material models for fusion applications

To enable future innovative designs for fusion platforms on the Z machine, a Sandia LDRD team developed an automated framework for constructing material models. This directly addressed the challenge of creating comprehensive material models that can leverage machine learning and integrate data from multi-fidelity datasets, something vital for uncertainty quantification analyses of magnetohydrodynamic codes. This project, which included collaborations with Los Alamos and Lawrence Livermore national laboratories and multiple universities, was presented on at IEEE International Conference on Plasma Science and the American Physical Society Division of Plasma Physics. Future projects will explore additional materials of interest to the NNSA and leverage machine learning frameworks for model refinement. (PI: Lucas Stanek)

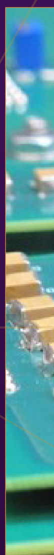
READ MORE > *Physics of Plasmas* (*May 2024* – Editor's Pick) (*October 2024* – Editor's Pick)

LEVERAGING NEW TALENT > PI Lucas Stanek transitioned from a Maxwell Postdoctoral Fellow at Sandia to a staff member during this project.

Utilizing research innovations to propel high power microwave test capabilities

Sandia researchers are enhancing high power microwave test capabilities through innovative solid-state pulsed power and radio frequency generation. This work, which advanced semiconductor opening switches in the U.S., is enabling flexible qualification testing of our nation's most important assets. Essential collaborations include Texas Tech University, a leader in high power semiconductor devices for pulsed power, and Lawrence Livermore National Laboratory. Key contributors include Professors Stephen Bayne and Argenis Bilbao, research student David Graves, and Caitlin Chapin from Lawrence Livermore National Laboratory. (PI: Emily Schrock)

LEVERAGING NEW TALENT > Megan Lehmann from Texas Tech University and Mathew Rawson from Sandia National/Regional partner New Mexico Tech joined Sandia for summer internships and transitioned to year-round roles.



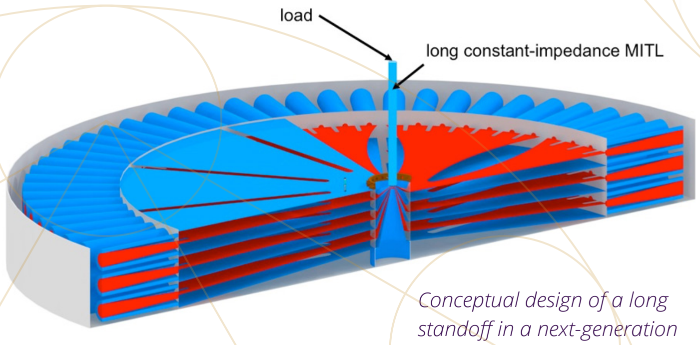
Characterizing power delivery and losses

In high yield fusion experiments (>100 MJ), it is necessary to protect personnel and equipment from blast debris and radiation. One path to achieve this is a coaxial magnetically insulated transmission line (MITL), long enough to provide temporal and spatial isolation (standoff) between the load and the generator. For example, a MagLIF pulse would suggest a roughly 20-meter long MITL.

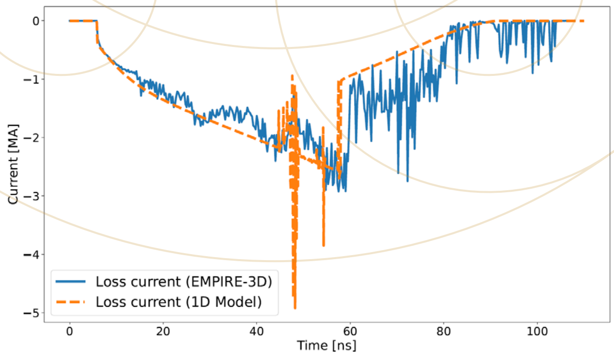
In a pulsed power fusion facility operating at large peak currents, a main concern is the ability to transport a large amount of power to the load with minimal losses. A recent project studied a 10m-long coaxial MITL prototype driven by a 60 MA current pulse. It was found that current losses did not exceed 5% and anode temperature rise avoided the desorption of contaminants and the formation of lossy plasmas.

Researchers developed a 1D model that is millions of times more computationally efficient than traditional tools and can be used for rapid exploration of potential designs. It was extensively verified against particle-in-cell simulations with Sandia's code EMPIRE. The underlying physics suggests existence of a large variety of MITL designs suitable for standoff. (PI: Evstati Evstatiev)

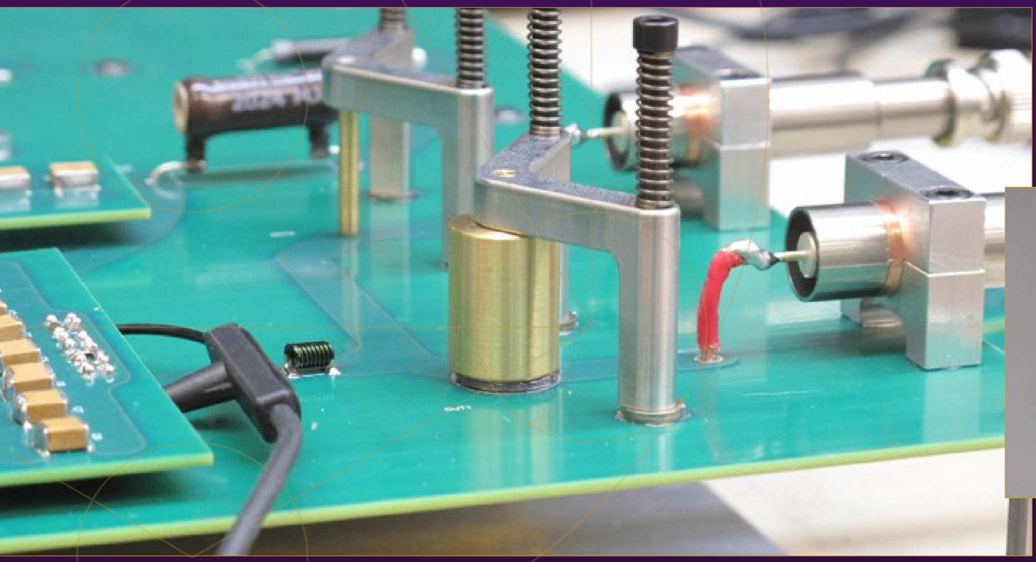
READ MORE > *Physical Review Accelerators and Beams*



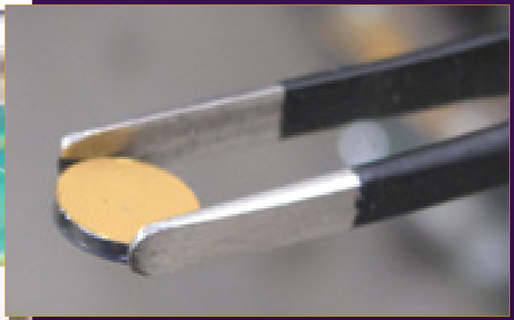
Conceptual design of a long standoff in a next-generation pulsed power facility.



Current losses calculated by particle-in-cell code EMPIRE and 1D model, showing losses less than 5% out of 60 mA.



Stacked semiconductor opening switch developed by Lawrence Livermore National Laboratory.



Evaluating semiconductor opening switch performance in Sandia's Advanced Compact Pulsed Power Test Facility.

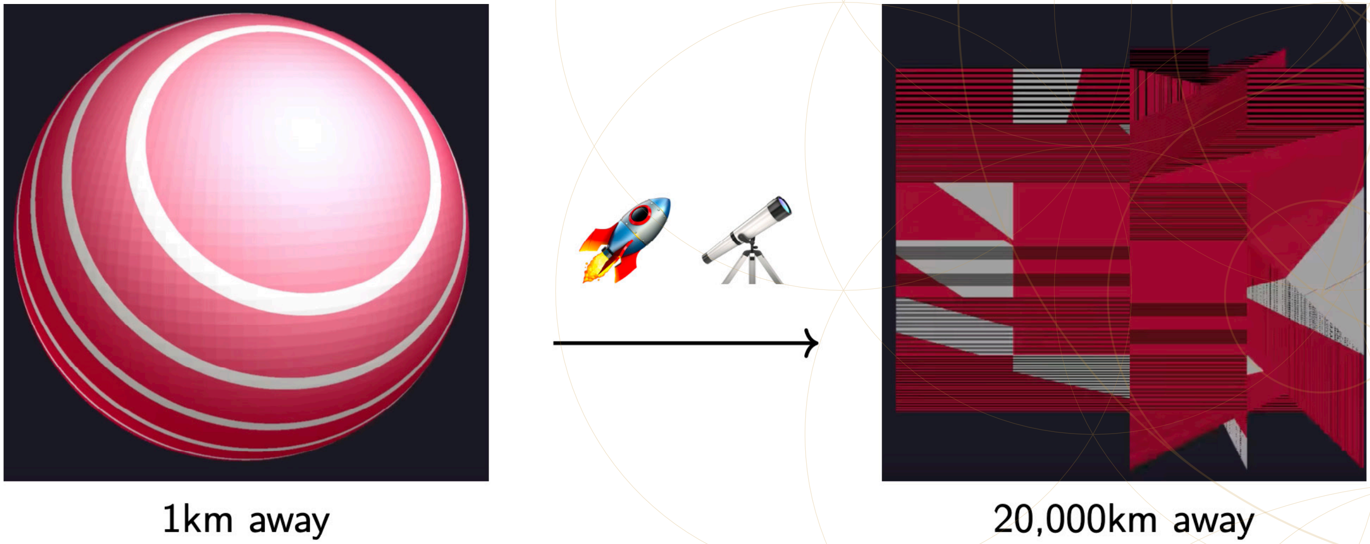
Improving assurance of high-consequence systems using formal methods and automated reasoning

Computers typically represent numbers one of two ways: fixed-point (via integers) and floating-point numbers. Floating point provides improved efficiency and productivity, but errors can accumulate if not managed carefully. Error from floating point is called roundoff error and has caused loss of life in past high-consequence systems. Sandia researchers investigated techniques for automatically computing the worst-case roundoff error for computer programs.

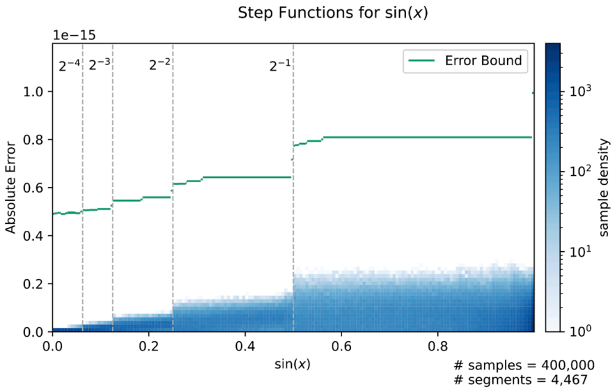
Research in collaboration with the University of Oregon resulted in improved techniques for understanding this error across all possible inputs. Sandia researchers led a collaboration with Oak Ridge National Laboratory, Pacific Northwest National Laboratory, NASA, and the French Commission for Atomic Energy to develop improvements to existing specification languages for roundoff error. These improvements will permit better analysis of floating-point roundoff errors. (PI: Samuel D. Pollard)

COOL FACT > This project will improve the safety and reliability of high-consequence embedded control systems while maintaining capability and programmer productivity.

LEVERAGING NEW TALENT > Anthony Dario, a PhD student intern, developed software and coauthored a manuscript for publication.



Error from imperfect computer representations of numbers when visualizing a sphere at 1km and 20,000km distance from an observer.



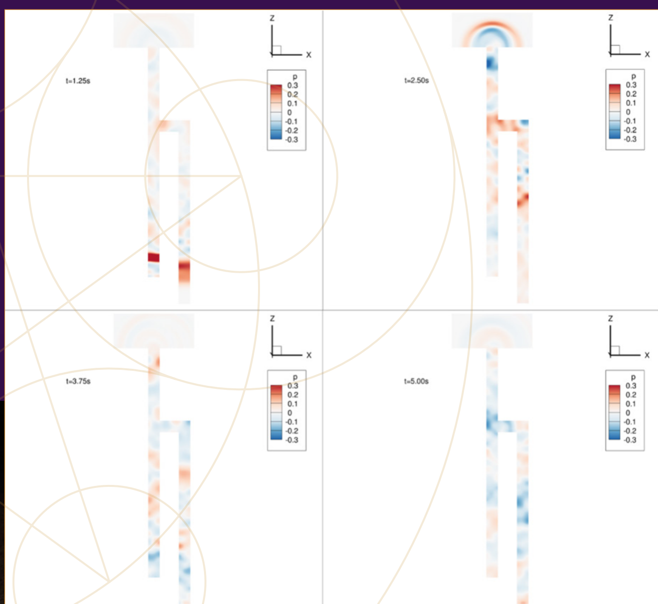
Worst-case error analysis (shown in green) provides understanding of numerical error without requiring program execution (shown in blue).

Advancing understanding of acoustic signals in underground tunnel structures

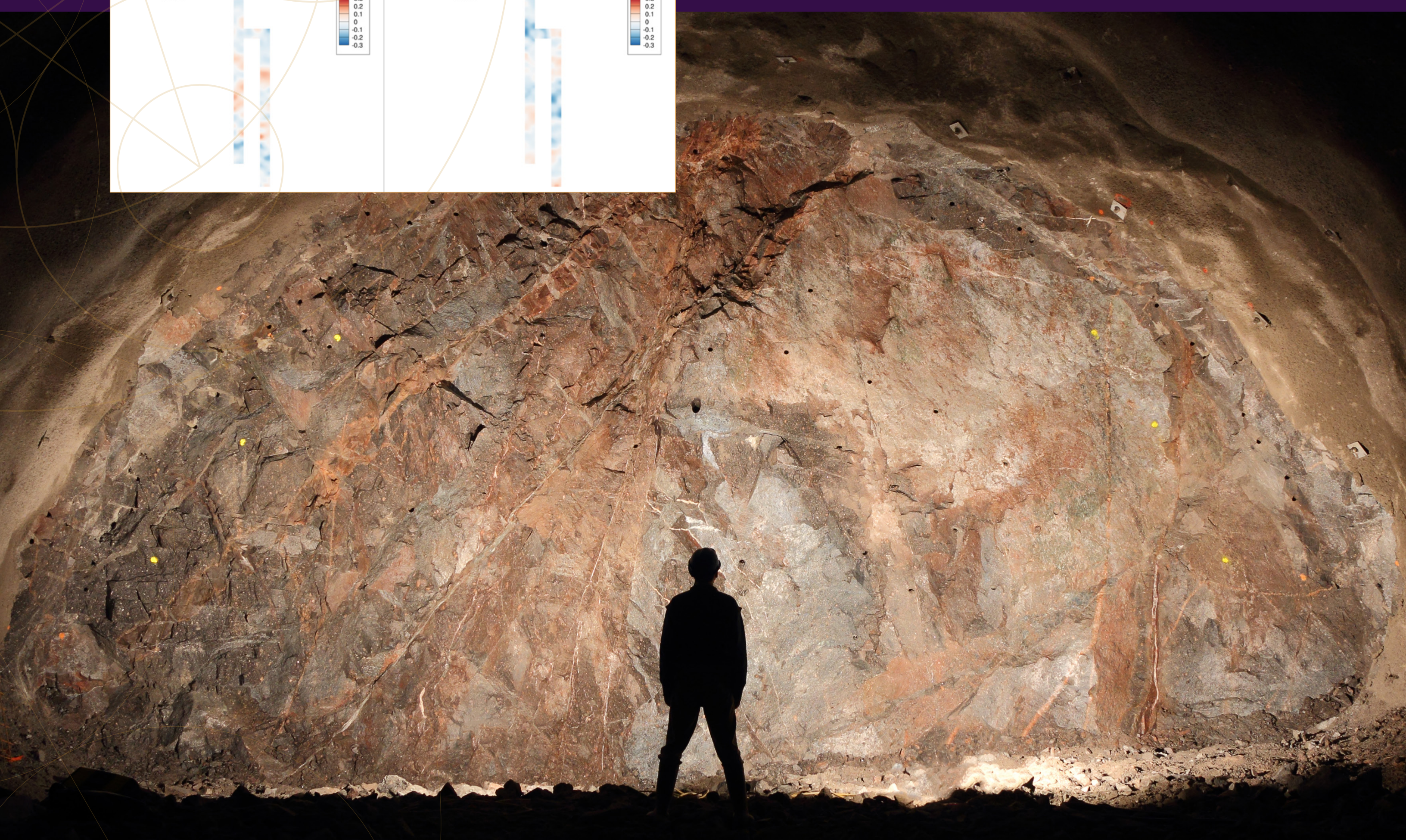
Sandia researchers are using remote data to determine the structure of underground tunnels. Specifically, their research focuses on understanding acoustic resonance in these structures, specifically how changes in tunnel configurations affect the acoustic signals observed from a distance. The potential benefits of this work were presented in May 2024 at the Acoustical Society of America Meeting in Ottawa.

Looking ahead, Sandia researchers have planned follow-on projects that will utilize numerical methods to analyze acoustic wave propagation and invert for underground tunnel structures. Additionally, the team will conduct a detailed analysis of the spectral content of these signals to fully exploit the valuable information they contain. This work not only enhances understanding but also improves safety and monitoring capabilities in critical situations. (PI: Nathan John Downey)

COOL FACT > The insights gained could significantly aid monitoring agencies that analyze acoustic signals from explosive events. With this research, these agencies can more accurately determine whether a specific signal originates from an explosion in an underground tunnel or cavity.

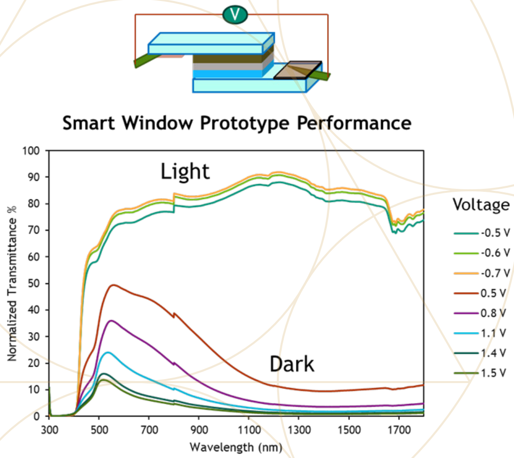


The images illustrate how sound travels through a branching underground tunnel.



Reducing energy consumption using innovative smart window coatings

By developing innovative plastic smart window coatings, LDRD researchers are addressing ways to increase energy efficiency. These coatings can quickly adjust solar energy transmission based on applied voltage, providing a cost-effective solution that avoids reliance on strategic minerals. The potential benefits are significant: Sandia's smart windows could greatly reduce electricity consumption by lowering heating, cooling, and lighting demands in buildings.



This innovative smart window prototype effectively manages solar energy transmission with simple voltage adjustments.

Collaborating with chemistry experts from Sandia Alliance partner University of New Mexico such as Wassie Takele and Professors Terefe Habteyes and Dongchang Chen, Sandia researchers gathered spectroscopic images to understand coating performance.

Findings were presented at the Electrochemical Society Meeting, and future projects will focus on assessing smart window aging and scaling up production. (PI: Nathan Hahn)

READ MORE > *ACS Applied Optical Materials*, *Energy and Buildings*

COOL FACT > This research supports energy and homeland security by reducing electric grid loads and could enhance national and global security through improved thermal control for vehicles and spacecraft.

LEVERAGING NEW TALENT > Postdoc Simranjit Grewal played a key role in this project.

Transforming lidar imaging with compact, polarization-enhanced sensors

Lidar is crucial for security or autonomous navigation, but in real-world environments, signals have noise that obscures objects of interest, degrading scene analysis. Sandia researchers are addressing this challenge by exploiting polarization diversity to cut through clutter with a single compact sensor (Fig. 1).

Sandia's insight was reconsidering how light interacts with surfaces. The reflection of light depends on the optical properties and surface quality of the encountered object, which affects the polarization state of the returning signal. Traditional lidar systems only capture signal intensity and miss this critical information. In contrast, polarization-sensitive

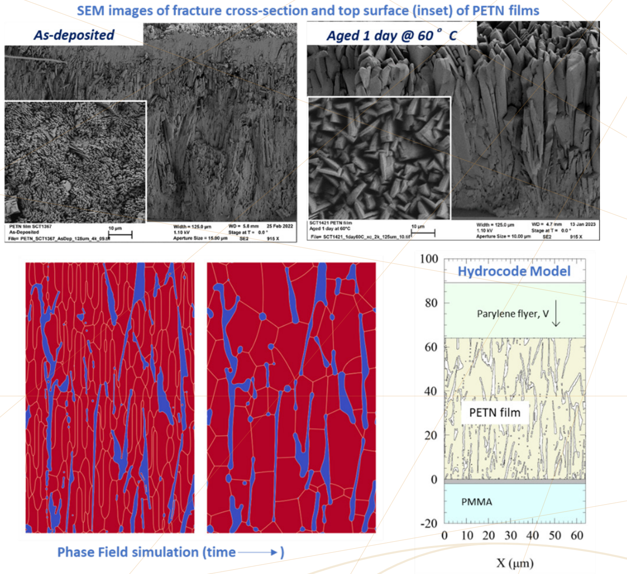
Fig. 1. A prototype lidar sensor utilizing silicon photonics technology developed by Sandia researchers.

Transforming explosive performance predictions using digital aging tools

Understanding how the performance of energetic materials, like explosives, will behave decades into their lifecycle is complex. To tackle this challenge, Sandia researchers focused on uncovering the physical processes driving changes and developing predictive models for performance.

The team successfully created a new phase-field modeling capability to forecast microstructure evolution over extended periods. By conducting experiments on precisely controlled films of explosive, Sandia researchers gained valuable insights into how aging conditions affect microstructure properties and initiation performance.

Collaborating with Sandia Alliance partners Purdue and Georgia Tech, the team published findings in top journals and presented at major conferences, such as the American Physical Society Biennial Conference. The results of this project are crucial for design engineers to ensure the safety and reliability of components throughout their lifecycle, with applications in the nuclear deterrence mission space. (PI: David Lee Damm)



Digital aging workflow connects experiments, microstructure changes, and performance predictions for explosive materials.

COOL FACT > This work led to a groundbreaking "digital aging" toolset that combines microstructure evolution models with hydrocode simulations, allowing for continuous performance predictions as materials age.

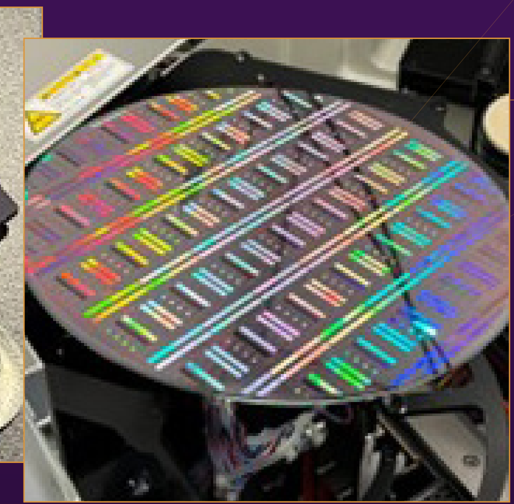
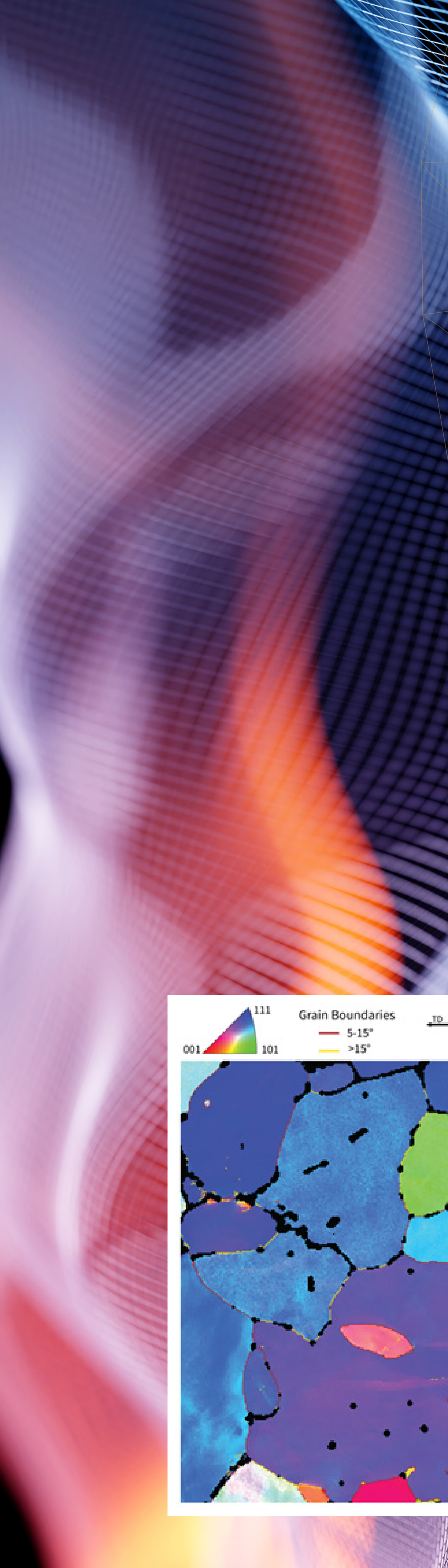


Fig. 2. A wafer featuring sensors with advanced materials to control the polarization of emitted light.

lidar captures this data, providing a powerful tool for sorting through information and eliminating unwanted clutter.

The goal of this LDRD project is to integrate advanced optical components onto low-power silicon photonics circuits to achieve novel sensors that manipulate and detect polarization states (Fig. 2). This allows for processing a de-cluttered data set and identifying unique signatures associated with targets of interest, resulting in higher performance with lower energy costs. (PI: Christopher Long)



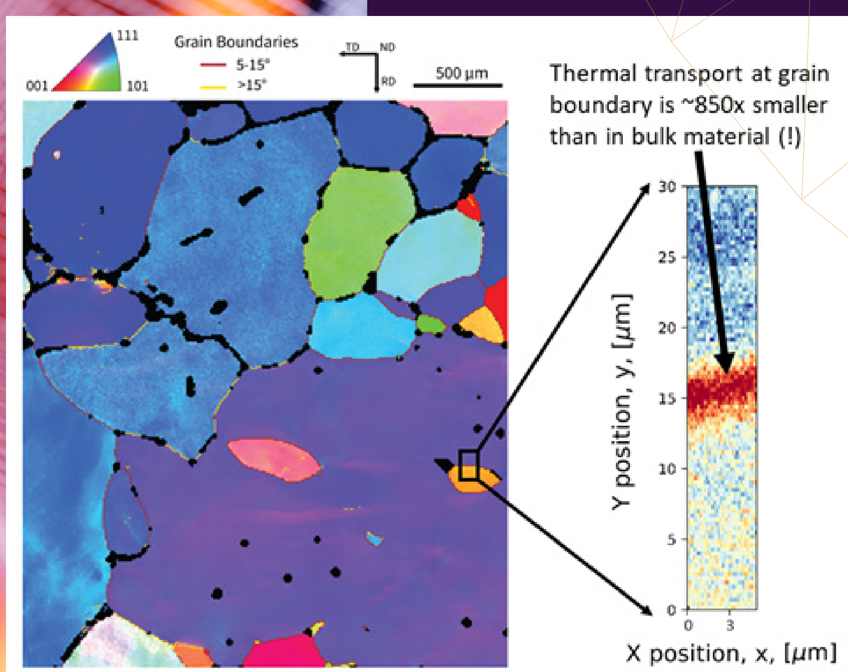
Enhancing power production efficiency with direct grain boundary measurements

Understanding how materials are used in thermoelectric generators, which convert heat into electricity, is critical for the nation. In groundbreaking work, Sandia researchers have tackled the challenge of measuring thermal transport at grain boundaries in multigrained materials.

Maximizing efficiency requires low thermal conductivity, often achieved by increasing the number of grain boundaries to impede heat transfer. However, direct measurement of thermal transport over individual grain boundaries was not previously accessible, limiting understanding of how grain boundary properties affect device performance. The LDRD team developed a novel technique to directly measure thermal transport at individual grain boundaries, using finite element models to interpret the data.

Key contributors included Oluwaseyi Balogun and Eleonora Isotta at Northwestern University. The team presented results at the 2024 Summer Heat Transfer Conference and plans future research focused on the interplay between synthesis methods, electrical conductivity, and thermal conductivity in thermoelectric materials. (PI: Wyatt Lea Hodges)

LEVERAGING NEW TALENT > Jakob Bates, a student intern at Sandia, performed thermal simulations for this project.



Electron microscope image of tin telluride grain sample's structure, along with a thermal image of the grain boundary.

Improving simulation accuracy and confidence for high-stakes engineering decisions

Sandia researchers are transforming material characterization and model calibration by interlacing the two. Traditional methods rely on simplified test specimens and global data, leading to inadequate characterization and no uncertainty quantification. These approaches are sequential, inflexible, and time-consuming.

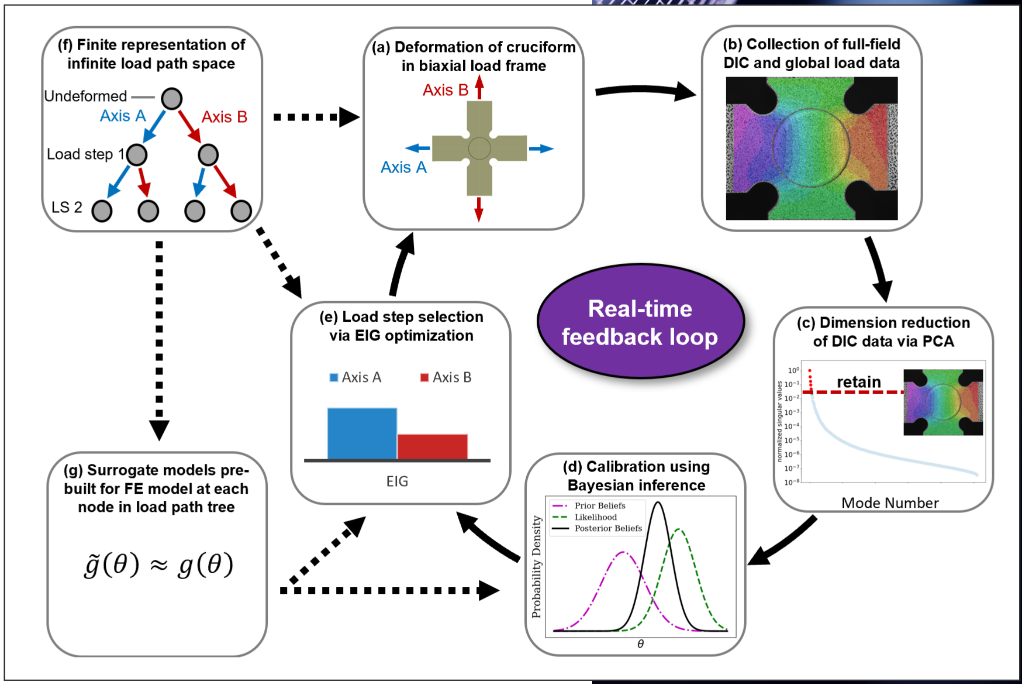
To address these challenges, the team developed a new approach called Interlaced Characterization and Calibration (ICC). This innovative workflow enhances model calibration by efficiently using full-field data to calibrate high-fidelity material models. The lynchpin of ICC is optimal experimental design that actively drives an experiment and calibration in a quasi real-time feedback loop.

This paradigm enhances modeling agility and boosts confidence in predictions, supporting informed engineering design decisions. (PI: Elizabeth M.C. Jones)

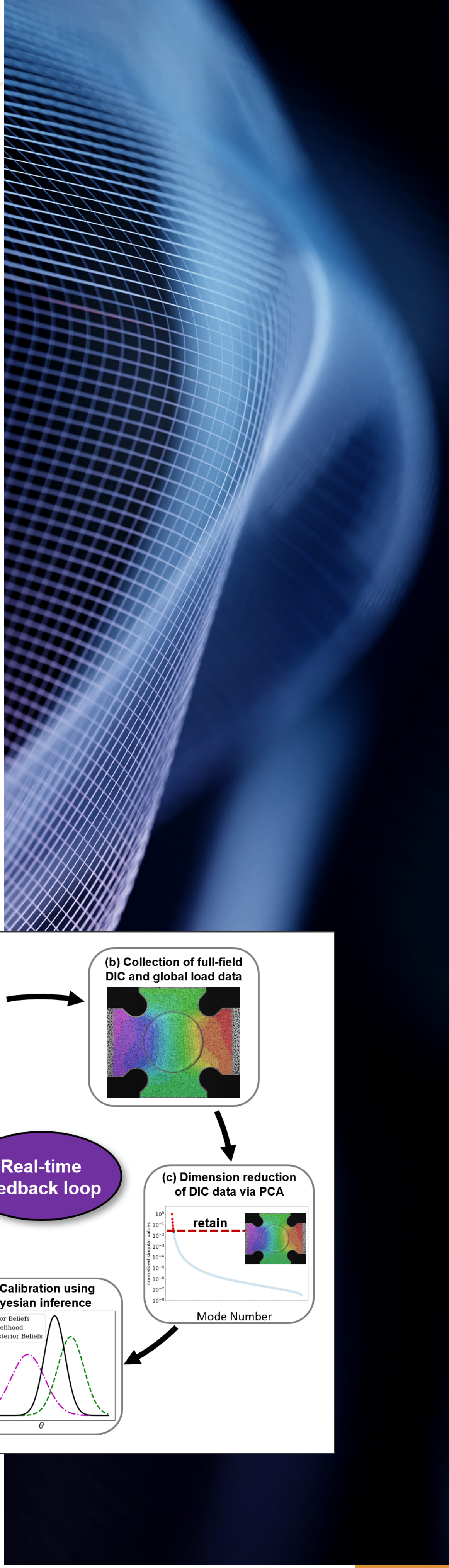
READ MORE > *International Journal of Mechanical Sciences*

COOL FACT > Interlaced Characterization and Calibration significantly increases efficiency, completing model calibrations in just one week—5 to 10 times faster than traditional methods. (This was validated through synthetic simulations and experimental testing with aluminum 6061.)

LEVERAGING NEW TALENT > Postdoc Denielle Ricciardi was instrumental in this project.



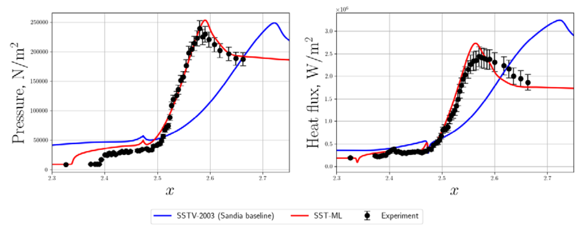
The Interlaced Characterization and Calibration framework is applied to a cruciform specimen under controlled biaxial loading.



Advancing turbulence models for hypersonic flows using machine learning

Sandia researchers utilized machine learning techniques to address the limitations of Reynolds-averaged Navier-Stokes (RANS) turbulence models in predicting hypersonic turbulent flows, with a particular emphasis on inaccuracies in wall heating predictions for flows involving shock boundary layer interactions.

This research has led to the development of neural-network-based machine learned turbulence models that provide state-of-the-art predictions for a range of hypersonic flows, along with a deeper understanding of RANS modeling for hypersonic flows and an understanding of current deficiencies in Sandia's modeling toolkit.



Model predictions for wall quantities-of-interest in a shock boundary layer interaction on a cylinder-flare geometry.

This project, a collaboration with the Sandia National/Regional partner University of Michigan, resulted in published papers and presentations at conferences organized by the American Institute of Aeronautics and Astronautics (AIAA) and NASA. The findings are relevant to various mission areas, including nuclear deterrence. Elements of the research are ongoing under the Advanced Simulation and Computing initiative, which aims to extend the applicability of the developed models. (PI: Eric Joshua Parish)

READ MORE > *AIAA Journal*

Improving aerospace reliability through new combined environment predictive design and testing

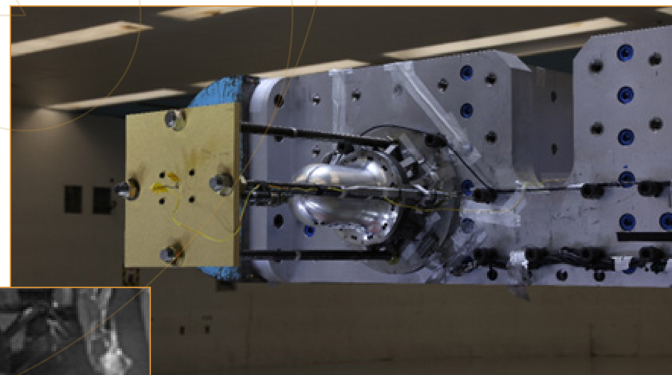
Sandia is advancing aerospace research to produce realistic flight environment testing by inducing shock events in conjunction with combined inertial and vibrational loads. This innovative work enables researchers to introduce tailored explosive shock loading with predictable load paths while simultaneously inducing controlled vibration and inertial mechanical environments.

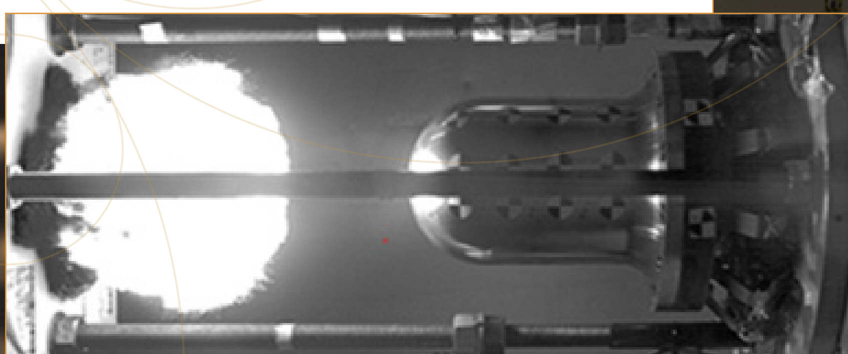
Sandia researchers, who collaborated with Professor Mike Hargather at Sandia National/ Regional partner New Mexico Tech (NM Tech), shared their findings through conference presentations at the 94th Shock and Vibration Exposition and the Society for Experimental Mechanics Annual Conference.

This work has the potential to be applied in nuclear deterrent design, validation, and qualification mission spaces, improving the agility of design and qualification activities for flight systems. (PI: James Nicholas)

COOL FACT > Follow-on projects with multiple nuclear deterrent systems groups will ensure continued advancements in reliability and safety for aerospace technologies.

LEVERAGING NEW TALENT > A crucial aspect of this research project included NM Tech students James Reeves and Robert Ivil.

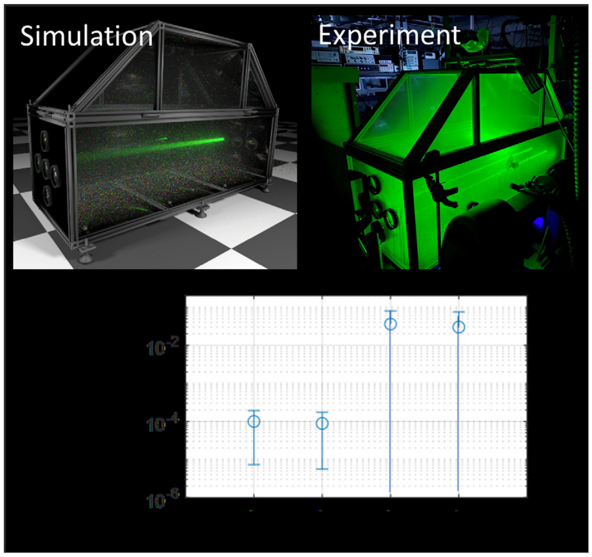




Top: *Sandia's team designed fixturing to shape a shock input to a tuned specification in a combined vibration and inertial test environment.* ***Left:*** *A high explosive event induces a shock event for combined environment testing.*

Testing a photon transport model against real-world experiments for improved simulation accuracy

How long does it take for photons to travel through clouds of particles in the air? Sandia researchers utilized a new photon propagation simulation tool based on the open-source Physically Based Rendering Toolkit software and compared its results to measurements taken in a well-characterized fog chamber. The findings showed that the simulation and measurements agreed within their uncertainties, providing confidence in the model.



Simulated and observed photon travel time agreed within uncertainty across the two cloud thicknesses (1, 2) under study.

This work produced tangible data, demonstrating that the new model can accurately simulate real-world photon transport. As a result, the team drastically reduced the risk in using these models in applied research.

The implications of this research extend to mission areas such as storm lightning signal prediction, long-distance optical data transmission through air, and directed energy applications. Looking ahead, Sandia plans follow-on projects, including a study of cloud-top light dispersion as observed by space-based sensors using laboratory experiments and the new simulation tool. (PI: Adam Les Hammond-Clements)

COOL FACT > This work confirmed that the travel time of photons can be predicted reliably.

LEVERAGING NEW TALENT > Christian Pattyn, a senior graduate intern, designed and performed the experiments for this project.

Expanding applications of optical filters in explosive and chemical analysis

Sandia researchers are tackling the challenge of advancing Multivariate Optical Elements, or MOE, for spectral analysis. These innovative optical filters encode spectral information, significantly reducing data complexity. The team's project focuses on using MOE to distinguish explosive events and static chemical signatures, offering advantages over traditional hyperspectral imagers in power efficiency, signal levels, and temporal resolution.

By applying regression techniques to radiometric data and Fourier transform infrared spectrometer data, Sandia researchers aim to estimate active metal mass and differentiate heavy-metal-bearing molecules from background soil. Initial findings show promise in identifying metal masses, particularly at higher levels. The project lays the groundwork for developing more efficient spectral analysis tools for identifying explosive events. (PI: Patrick Barnett)

COOL FACT > This work could potentially be incorporated into compact, lightweight, and energy-efficient sensors deployed on drones or satellites to detect explosions or chemicals.

Accelerating target detection in SAR with innovative colorization techniques

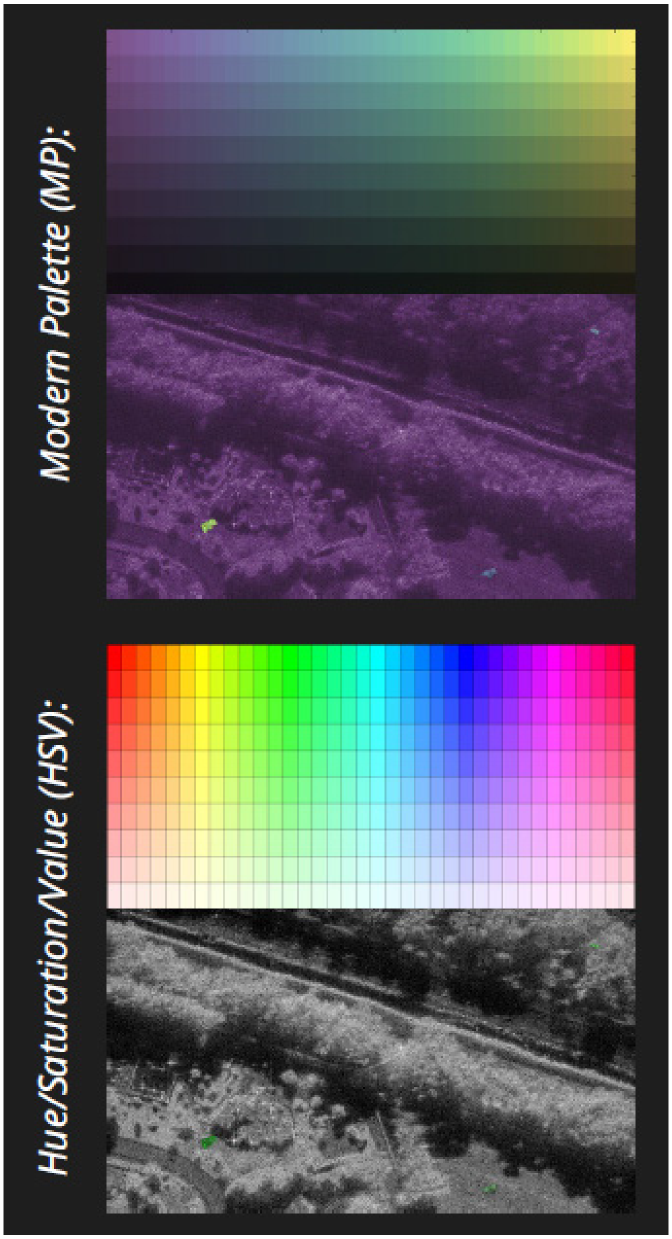
Sandia researchers are exploring innovative ways to increase analysts' visual detection of features in Synthetic Aperture Radar (SAR) images by colorizing additional features.

To achieve this, Sandia evaluated the effectiveness of traditional Hue/Saturation/Value (HSV) color schemes against modern perceptually uniform palettes derived from data visualization and cognitive science. The team conducted three experiments with 770 participants, testing various color variants for target detection tasks.

The results were compelling. In challenging clutter environments, the modern palettes enabled analysts to detect approximately 45% more targets compared to the best traditional hue. However, in simpler environments, color choice had less impact on detection rates.

Sandia researchers have developed data-backed recommendations on the advantages and limitations of modern palettes, along with a MATLAB toolkit for implementing these color schemes in new SAR products. Future efforts will focus on automating feature colorization and testing these palettes across new mission spaces, ensuring continued advancements in detection capabilities. (PI: Kristin Divis)

COOL FACT > The modern palettes led to responses that were 19-25% faster and preferred up to 13 times more than traditional hues.



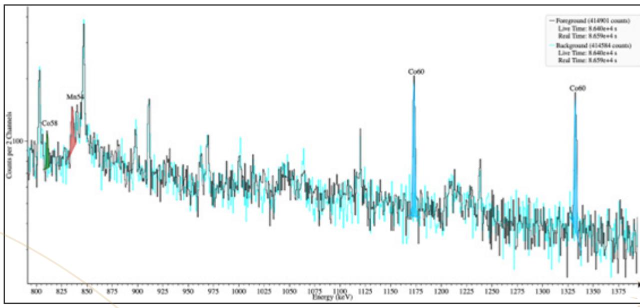
Use of a modern palette color scheme, drawn from data visualization and cognitive science domains, increased detection of targets in challenging clutter environments (45% more detects) compared to even the best HSV hue.

Confirming dismantlement of nuclear warheads while protecting sensitive information

When it comes to nuclear arms control, verification is essential. By detecting unique metastable radionuclide signatures in non-nuclear material disposition pathways, an LDRD research team created a reliable verification measure to confirm dismantlement of nuclear warheads without disclosing sensitive information.

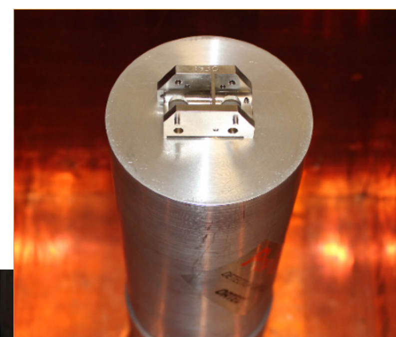
The implications of this research extend to critical mission areas, including nuclear arms control and nuclear search operations.

Looking ahead, Sandia plans follow-on projects, including a measurement campaign at the Y-12 National Security Complex in a multi-laboratory collaboration, as well as a proposal to the Defense Nuclear Non-Proliferation Research and Development program to measure signatures of non-nuclear materials at Pantex throughout their disposition process. Sandia researchers recently presented this work at the 65th Annual Meeting of the Institute of Nuclear Materials Management. (PI: Peter Marleau)



The gamma-ray spectrum from the stainless-steel bracket shows neutron transmutation signatures, indicating long-term use in a nuclear warhead.

COOL FACT > Sandia has developed a robust method that can confirm the authenticity of declared warheads and ensure that these items have been dismantled, all while protecting classified design information.



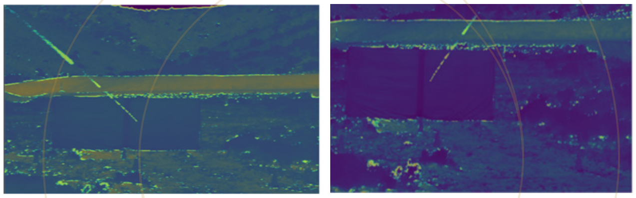
Inside a low-background shield, a high-purity germanium gamma-ray spectrometer measures a dispositioned stainless-steel bracket

Researcher Peter Marleau led an LDRD team that developed a method for confirming dismantlement of nuclear warheads while protecting sensitive information. (Photo by Dino Vournas)

Enhancing target tracking with Sandia's advanced detection techniques

Sandia researchers have made significant strides in tracking low-signal, high-speed objects, a challenge that persists despite advancements in imaging systems. Successfully tracking ballistics enhances system lethality and survivability, while advancements in counter-uncrewed aircraft systems (UAS) address the complexity of engaging small, fast-moving targets. Sandia developed a prototype system that delivers 3D target tracking on a size, weight, power, and cost-constrained platform.

Researchers utilized Temporal Frequency Analysis (TFA), a Sandia-patented algorithmic process, to enhance the detection of fast-moving pixels. UAS and ballistics experiments validated the robustness of TFA-enabled stereo processing algorithms.



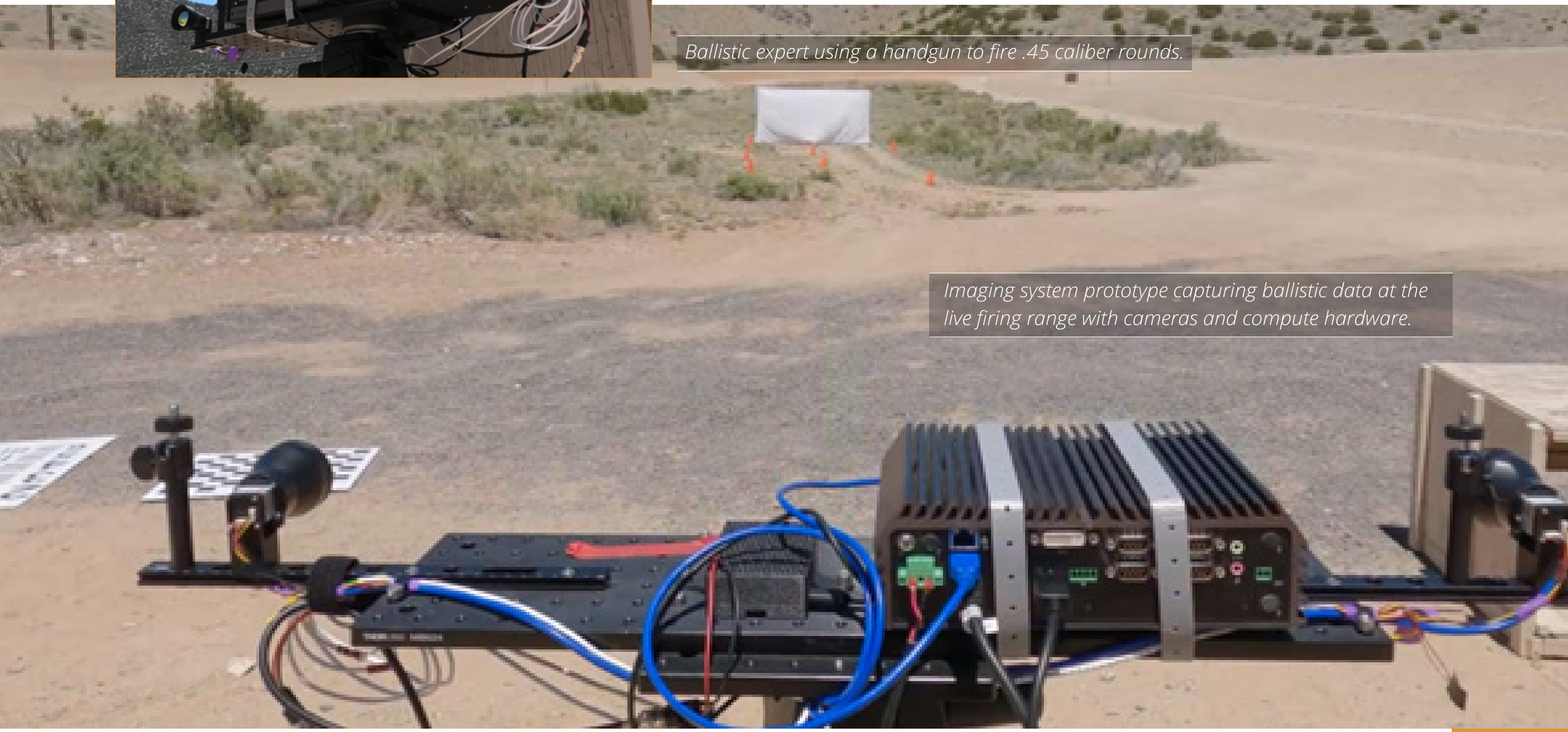
Left and right stereo images of .45 caliber ballistics with Temporal Frequency Analysis algorithm applied.

Researchers collaborated with professors from Alabama A&M (a Sandia Securing Top Academic Research & Talent at HBCUs partner) who possess expertise in image processing and low-contrast target detection. Follow-on projects leveraging this work are underway. (PI: Jaclynn Javonna Stubbs)

COOL FACT > The team developed innovative techniques for the passive detection of incoming and outgoing targets, particularly in fields of ballistics and UAS tracking.

LEVERAGING NEW TALENT > Contributions from Sandia intern Michael Mardikes, who presented at the Sandia 6th Annual XR Conference, were integral to the project's success.

Ballistic expert using a handgun to fire .45 caliber rounds.



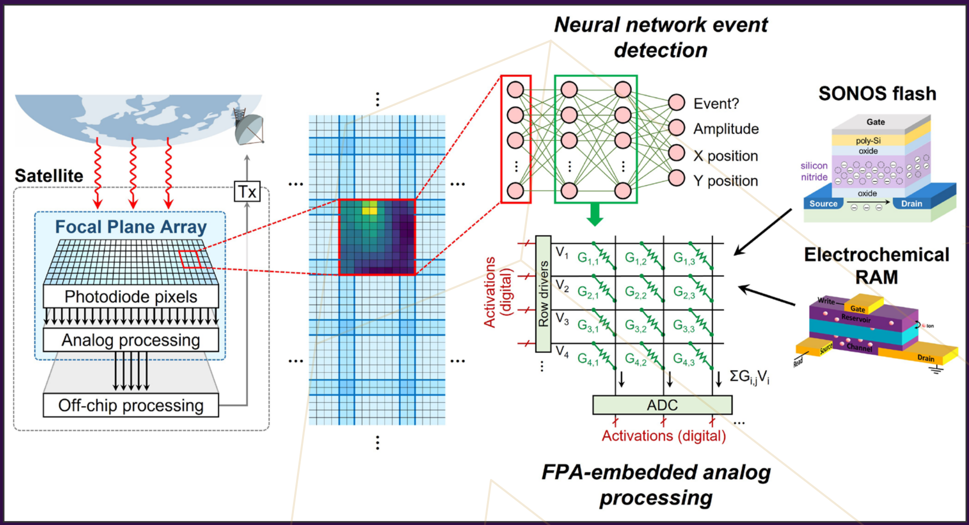
Imaging system prototype capturing ballistic data at the live firing range with cameras and compute hardware.

Revolutionizing space-based object detection using advanced analog computing techniques

Next-generation space-based remote sensing systems require data from imaging arrays to be processed at unprecedented speeds within the power constraints of satellites. To address this, compact convolutional and recurrent neural networks were developed to detect and estimate point-like events in cluttered environments.

The project utilized two types of analog memory devices: a large array of silicon-oxide-nitride-oxide-silicon (SONOS) charge-trap memory, which is currently a more mature memory technology, and electrochemical memory (ECRAM), which is inherently resistant to radiation. Sandia researchers demonstrated accurate end-to-end processing of neural networks on SONOS and characterized the radiation response of both SONOS and ECRAM.

Collaborations with Sandia National/Regional partners Arizona State and the University of Michigan were vital for testing and fabrication. Sandia researchers are pursuing follow-on projects with the DOD, Defense Advanced Research Projects Agency, and Air Force Research Laboratory to further enhance these technologies.
(PI: Patrick Xiao)



Satellite remote sensing system architecture integrating analog neural network processing directly into the focal plane array.

READ MORE > *IEEE Transactions on Nuclear Science* (*1*) (*2*); *Proceedings of the National Academy of Sciences (PNAS)*

COOL FACT > Sandia's compact convolutional and recurrent neural networks were implemented on novel analog in-memory computing systems, which can eventually be 10 to 1,000 times more energy-efficient than traditional digital processors.

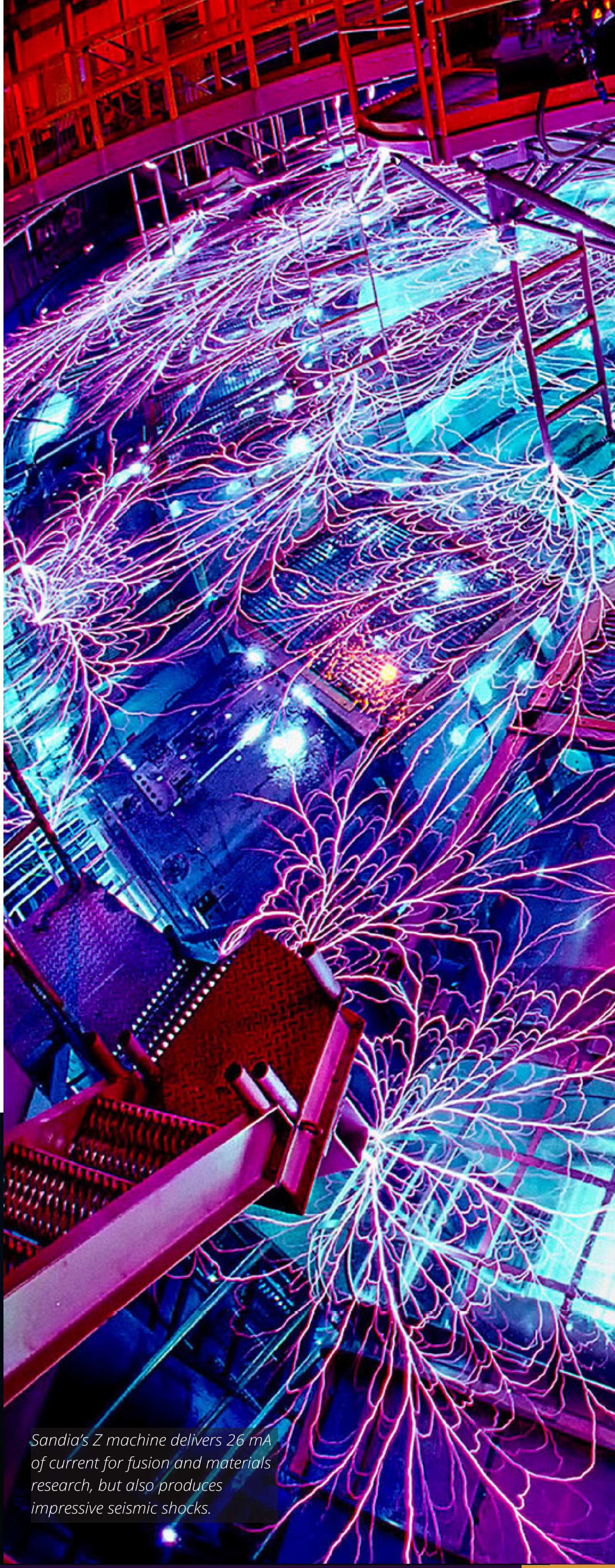
Using Sandia's Z machine as a seismic source

Sandia's Z machine is well-known for its impactful work in inertial confinement fusion and materials research. During every experiment, the Z machine also produces seismic and infrasound signals that are detectable several kilometers away. (Infrasound refers to sound waves too low for people to hear.)

The research team monitored signals from Z machine, determined they are repeatable, and demonstrated in the results that Z can be used as a reliable source for seismic and infrasound signals. This ability will help Sandia researchers better understand seismic and infrasound propagation in noisy, urban environments. (PI: Seth Root)

COOL FACT > Sandia's discovery will support the testing and development of sensors and analytic techniques for detecting nuclear tests and advancing other non-proliferation efforts.

LEVERAGING NEW TALENT > Early career Sandians Nora Wynn and Christian Stanciu lead the infrasound and seismic detection and analysis team and contributed significantly to this project.



Sandia's Z machine delivers 26 mA of current for fusion and materials research, but also produces impressive seismic shocks.

Distinguished Sandia chemical engineer Anne Grillet was recognized by the Society of Women Engineers for demonstrating a variety of outstanding career leadership activities in a technical field. (Photo by Lonnie Anderson)

Improving process parameters to prevent runout in active brazing applications

Sandia researchers are tackling poor yields in active brazing, a process used to join metals and ceramics. By understanding the science behind low yields, Sandia aims to improve outcomes for multiple mission areas.

University collaborators at Sandia Securing Top Academic Research & Talent at HBCUs partner North Carolina A&T, Alliance partners Texas A&M and the University of Illinois Urbana-Champaign, and Penn State have helped explore critical aspects of the process, including developing new models for materials transitioning from fluid to solid and studying the bonding of the braze alloy to the ceramic.

Sandia has published findings and presented at TMS and the American Physical Society on this research, which shows potential to enhance multiple mission areas. Future projects following on to this work focus on braze joint strength under thermal shock and the chemistry of brazed ceramic surfaces. (PI: Anne Grillet)

READ MORE > *Computers and Fluids*

LEVERAGING NEW TALENT > Key contributors include postdoctoral researchers Ian Winter, Eric Rothchild, David Kemmenoe, and Bryce Thurston. Student interns Gustav Bourdon, John Hickman, Danielle Edwards, and Warner Dorman also played vital roles. Technologist Anthony McMaster completed his master's degree while working on this project.

Developing integrated photonic encoders for low power and high-speed image processing

Researchers on this team wanted to address the bottleneck of power consumption and data storage in high-data-rate imaging systems, so they developed analog photonic encoding systems to compress, denoise, and classify images with 1000x less power and faster speeds compared to existing digital systems.

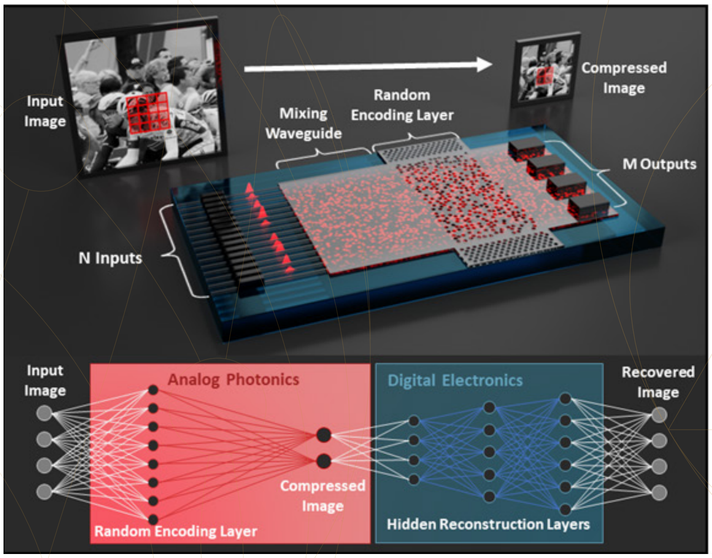
This work was conducted in collaboration with several academic and industry partners, including the U.S. Naval Research Laboratory, Sandia National/Regional partner University of Arizona, and University of Central Florida. The research team filed four patents and presented their findings at various conferences and invited talks. This research will continue under a Sandia Grand Challenge and an external DOD-funded Small Business Technology Transfer program. (PI: Raktim Sarma)

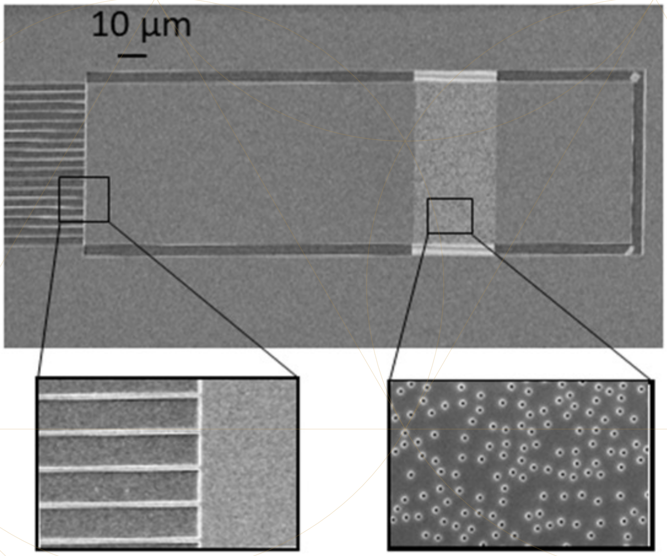
READ MORE > *Communications Physics*, *Nature Communications*, *Photonics Research*, *Crystal Growth & Design*

COOL FACTS >

- These integrated photonic encoders could improve autonomous surveillance systems, transform surveillance applications, extend mission lifetime, and advance edge computing systems.
- The technology can also benefit agriculture, disaster management, urban planning, and resource exploration, all of which utilize drone or satellite imagery.

LEVERAGING NEW TALENT > This project promoted diversity in STEM by supporting Purdue PhD student Nirali Bhatt. Bhatt is interested in joining Sandia as a postdoc after graduation. This project also supported two graduate interns Andrew Klein and Isaac Stricklin.





(Left) Schematic showing the working principle of the integrated silicon photonics-based all-optical image encoder for image compression. (Right) Scanning electron micrograph of the fabricated silicon-photonics based all-optical image encoder for compression and denoising.

Optimizing size and power efficiency in resonator technology for critical missions

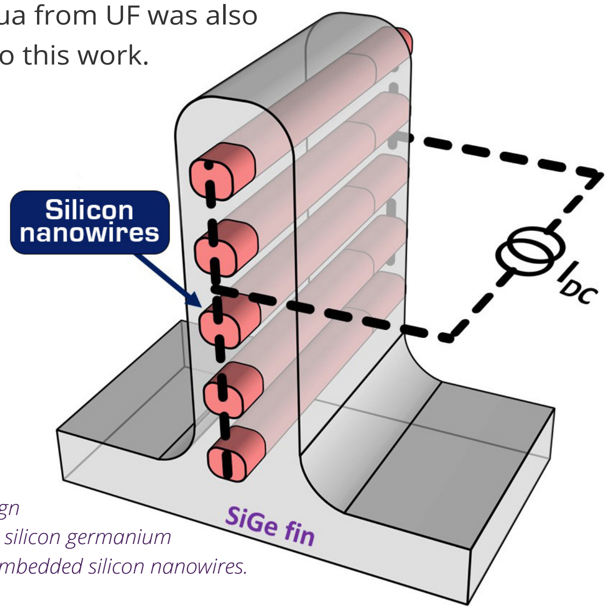
LDRD researchers and collaborators at the Sandia National/Regional partner University of Florida (UF) are working to enable super-high-frequency (SHF) resonator technology which utilizes a novel concept known as self-amplification. Collaborations with UF Professors Kevin Jones and Roozbeh Tabrizian, were key to this project.

Project success includes demonstration of self-amplification in novel resonators comprised of a silicon-silicon germanium layered material in the low frequency range. The findings were shared at conferences including the 2024 Electronic Materials Conference and the 2024 Hilton Head Microsystem Workshop.

Critical mission area applications of this work include spanning tactical positioning, navigation, and timing, integrated spread-spectrum clocks for processors, 6G communications, and phased array radars. (PI: George T. Wang)

COOL FACT > This project looks to revolutionize the size, weight, and power efficiency of on-chip resonators, offering game-changing advantages over existing technologies.

LEVERAGING NEW TALENT > Troy Tharpe transitioned to a Sandia postdoc position during this project, and Keshab Raj Sapkota converted from postdoc to staff. Ph.D. student Norma Passalacqua from UF was also essential to this work.



Self-amplified resonator design consisting of a silicon germanium nanofin with embedded silicon nanowires.

Boosting power densities in electronics with robust diamond substrate integration

Using an intermetallic compression bond, Sandia researchers are addressing thermal management in gallium nitride semiconductor devices by incorporating diamond substrates bonded to them. The team overcame challenges in integrating electrical contacts at the bonded interface for device conduction and has developed robust characterization and bonding processes.

The benefits for this approach include a reliable method for integrating high-quality diamond with power devices, enabling operation at higher power densities without exceeding temperature limits. This bonding process is also versatile, allowing integration with materials like silicon and applications across analog and digital circuits.

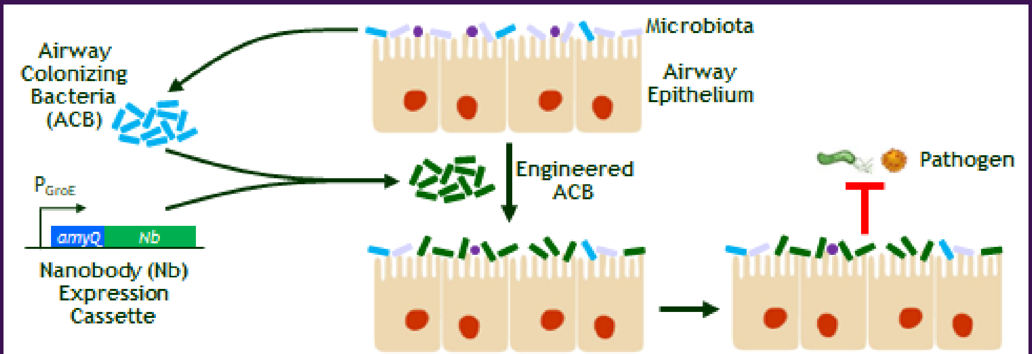
Collaboration with the Massachusetts Institute of Technology has been crucial for understanding transport phenomena, as have the multiple postdocs/students who supported the project. Presentations at major conferences showcased the potential of this technology across various mission spaces, including heterogeneous integration and power electronic systems. Insights from this project have led to follow-on LDRD investments. (PI: Luke Yates)

Developing engineered probiotics to combat respiratory infections

Sandia researchers are focused on protecting soldiers and citizens from biological threats by creating innovative solutions to prevent and treat infectious diseases, especially those affecting the respiratory system. Advances in synthetic biology have led to the concept of "living countermeasures," where cells are genetically engineered to act as sensors and deliver treatments inside the body. This led to engineering probiotics to fight infections.

Building on this foundation, the LDRD team identified specific bacteria that can infiltrate and live within the microbiome in the respiratory tract of mice, and located simplified antibodies, known as nanobodies, that can neutralize respiratory pathogens. After these discoveries, they worked to modify these bacteria to produce nanobodies in the respiratory tract, enhancing defense against infections.

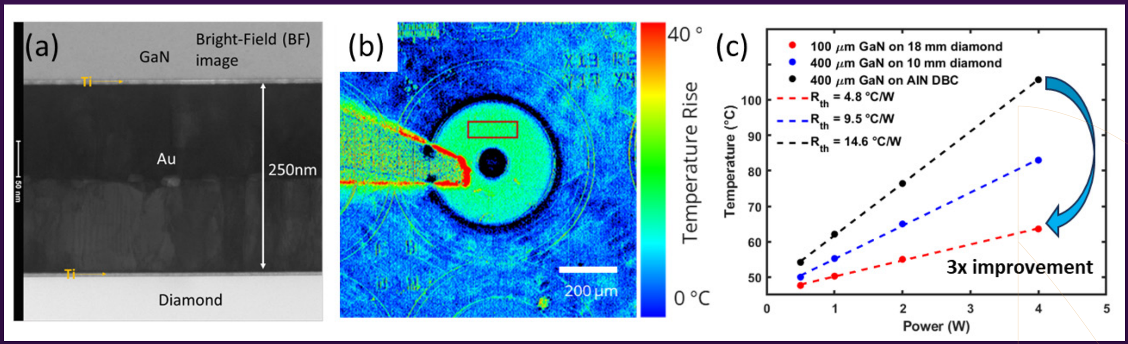
Through their successful project and collaborations with Sandia Alliance partners Georgia Tech and UC Berkeley, they successfully engineered the bacteria to produce nanobodies that neutralize SARS-CoV-2 and are testing their ability to protect mice from COVID-19. Future work will explore other pathogens and applications. The team is preparing two publications and will present their findings at upcoming conferences. (PI: Steve Branda)



Bacteria from the airway are engineered to secrete nanobodies, improving protection against respiratory infections

READ MORE > *Journal of Applied Physics*, *ACS Applied Materials & Interfaces* (*1*) (*2*)

LEVERAGING NEW TALENT > Key contributors include postdoc William Delmas and graduate student interns Logan Antiporda and Esteban Cook.



(a) Cutaway view of the bonded area. (b) Temperature measurement of the device. (c) Measured thermal resistance comparison.

Enhancing decision-making through improved information quality assessment techniques

A Sandia team is tackling the challenge of poor information quality and its impact on decision-making within organizations. Their research advances science in three key areas: enhancing situational awareness using advanced data science to collect information from multiple sources, accounting for structural and cognitive differences in organizational simulations, and quantifying the resilience of complex systems.

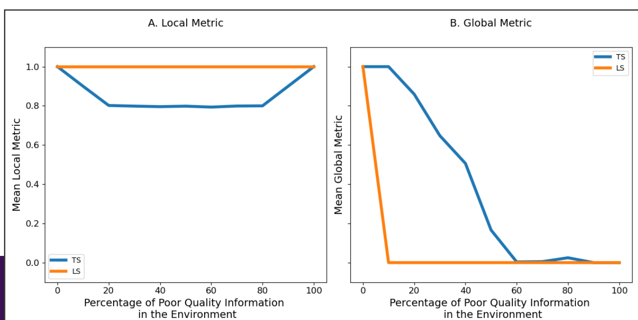
Collaborations with universities, such as the Sandia Alliance partners UT Austin and the UC Berkeley, have led to valuable insights from information technologies and a patent submission.

Follow-on projects are underway with multiple U.S. Government customers, including the Departments of Energy and Defense. (PI: Thushara Gunda)

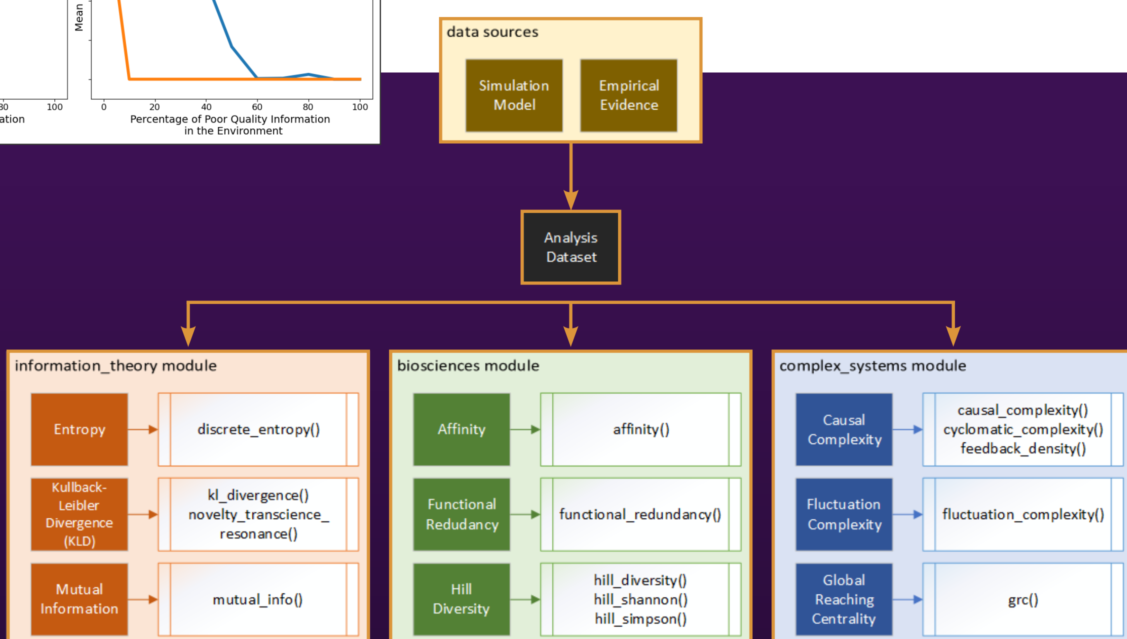
READ MORE > *International Conference on Systems Engineering International Symposium*, *IEEE Access*, *SoftwareX*

LEVERAGING NEW TALENT > This project has fostered professional growth, converting intern Ken Kliesner into a full-time hire, and supporting early-career researchers in achieving their first peer-reviewed publications and conference presentations.

Poor information quality disrupts organizations at every stage, from gathering data to making decisions.



Assessing the impact of poor quality information on tightly structured (TS) and loosely structured (LS) organizations.



Architecture for an open-source Python package that enhances resilience in complex systems.

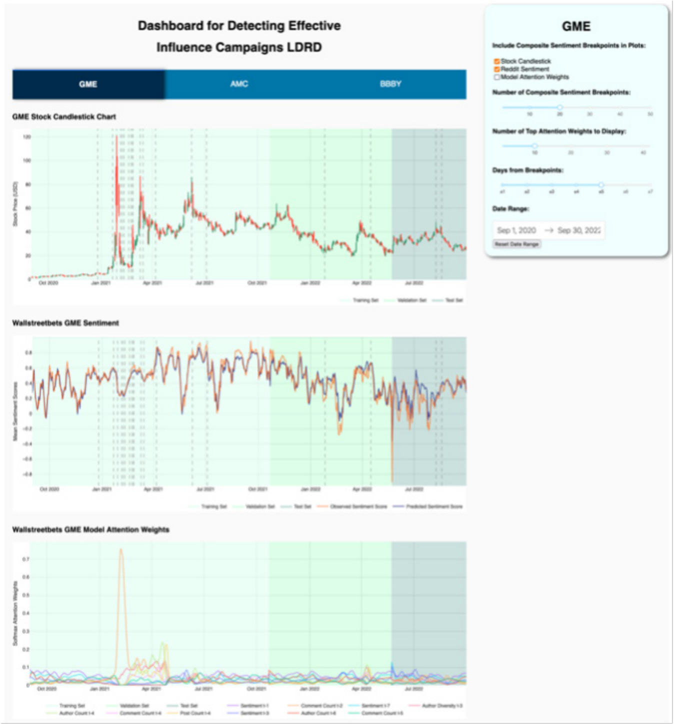
Detecting effective foreign Influence campaigns

Influence campaigns by foreign adversaries pose a growing risk to national security. To prevent harm from these attacks, this project developed a capability for detecting influence campaigns in social media data that is likely to have significant effects on prevailing opinion or real-world action. The project's integrated method combined data science with modeling and simulation.
It incorporated three types of analysis that were integrated into a dashboard capability:

1. Persuasiveness of messaging: Natural language processing was leveraged to identify indicators that online influence is likely to significantly shift prevailing opinion.
2. Anticipate action: A combination of theory-based simulation and natural language processing was employed to predict the likelihood of real-world action from emotional content and dynamic patterns in social media data.
3. Adversarial strategy: Reinforcement learning was used in agent-based simulation to identify potential defenses against the most effective adversarial influence strategies.

The project resulted in one staff hire, multiple publications, and eleven conference presentations. (PI: Asmeret Bier Naugle)

READ MORE > Computational and Mathematical Organization Theory (*1*) (*2*), *System Dynamics Review*



Dashboard capability comparing time series of real-world action, online sentiment, and key correlated features.

Driving innovation in statistical learning for real-time threat detection

Sandia researchers developed SEQUANA (Sequential Anomaly Analysis), a suite of statistical learning algorithms for real-time anomaly detection in high-dimensional, multimodal, and large-scale data streams. SEQUANA combines novel, general algorithms—such as memory-efficient decision-making in resource-constrained environments and geometric learning to reveal intrinsic mathematical properties of anomalies—with specialized approaches for high-consequence systems. These include a decision-theoretic framework driven by expert elicitation, and meta-analyses of correlated streaming p-values, successfully applied to cyber, mechanical, and seismic data. All algorithms provide theoretical guarantees and efficient uncertainty quantification, ensuring reliable deployment against mission-critical threats.

Lekha Patel is a mathematician and computational statistician at Sandia who led the research team that developed SEQUANA (Sequential Anomaly Analysis).

Vital student contributions, supported by collaborations with the Sandia Alliance partners University of New Mexico and Texas A&M, and National/Regional partner University of Washington, propelled SEQUANA research to leading machine learning conferences. SEQUANA is now being expanded via a Defense Nuclear Nonproliferation initiative, and leveraged for foundational generative artificial intelligence research, amplifying its national security impact. (PI: Lekha Patel)

READ MORE > *Journal of Machine Learning Research*

Improving machine learning for imaging missions using Voronoi-based classification

Within the field of remote sensing, Sandia researchers and Strategic Partnership Program collaborators addressed a critical challenge—performing density-based clustering that scales to high-resolution and high-dimensional images for real-time applications. This was achieved by developing a fast, density-based clustering algorithm. The team also created an easy-to-use graphical interface to assist analysts with real-time analysis of remote sensing data.

Looking ahead, Sandia researchers plan to extend the clustering algorithm to handle streaming data and develop a procedure for automatically selecting algorithm hyperparameters using techniques from persistent homology. This project has potential applications in various mission spaces, including remote sensing, nuclear deterrence archiving, cybersecurity, and border security. (PI: Mohamed Ebeida)

READ MORE > *Zenodo*

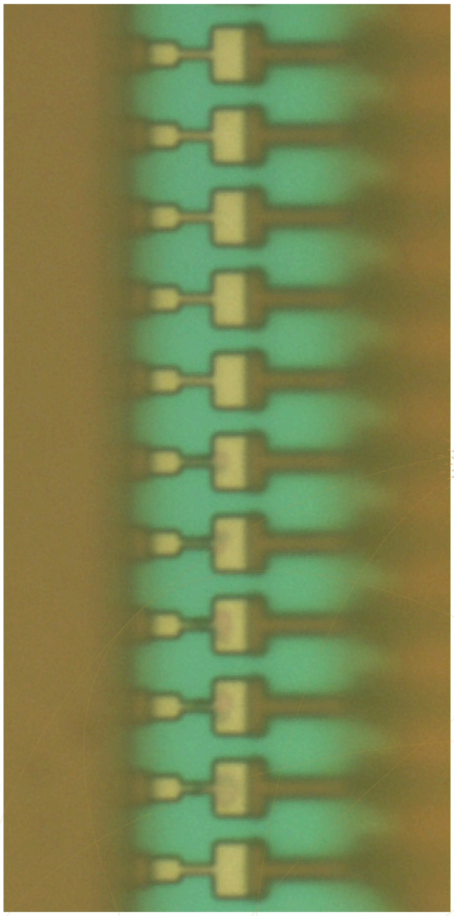
COOL FACT > This team developed a fast, density-based clustering algorithm that outperforms state-of-the-art methods on real-world remote sensing datasets.

LEVERAGING NEW TALENT > Nick Winovich converted from a postdoc to a staff member.

Accelerating program timelines with advanced configurable environmental-sensing technology

Sensing devices for environmental events are critical to high consequence systems, yet many sensors can only be configured during manufacturing, which adds months to years to realize sensor design changes. Sandia researchers developed a programmable electrical environmental sensing device that introduces Non-Volatile Memory (NVM) into the manufacturing process.

The developed Read-Out Integrated Circuit (ROIC) is a drop-in replacement for existing ROICs and due to the post-fabricated configurable NVM, this device can be configured with environmental stimuli (levels and timings) at any point post-production.



Magnified image of NVM displaying untouched, blown, and overblown fuses for analysis.

The ROIC immediately inserts itself as a viable option for future applications needing an electrical environmental sensing component without being burdened by the prolonged design and fabrication lead times. (PI: Drew Suchanek)

COOL FACT > This sensing device provides a configurable ROIC that can be acquired for any high consequence system and will save design teams from adding time to product realization schedules.

Developing agile fail-safe solutions for high consequence systems using advanced FPGA technology

Sandia researchers are pioneering the development of fail-safe circuits for future use in high consequence systems using Field Programmable Gate Arrays (FPGA). A fail-safe circuit ensures that if any single functional failure occurs, the system continues to operate correctly or safely, transmitting no critical data. While creating fail-safe circuits on FPGAs is more challenging than on Application Specific Integrated Circuits (ASIC), the potential benefits are significant. Implementing these circuits on FPGAs can drastically reduce realization times and enhance rapid agility.

The Sandia LDRD team focused on leveraging Sandia's proprietary FPGA, while collaborators Professor Jim Plusquellic from Sandia Alliance partner University of New Mexico explored an open-source FPGA.

Future projects will aim to improve the verification of fail-safe circuits, enabling the implementation of more complex designs on FPGAs. The team published "Fail-Safe Logic Design Strategies Within Modern FPGA Architectures" in *IEEE Access (Volume 13)* and recently presented their collaborative work at GOMACTech 2023. (PI: Drew Suchanek)

LEVERAGING NEW TALENT > Graduate student Priya Bhatka from UNM partnered on this project.

Enhancing launch environment detection with powerless microsystem technology

Detecting launch environment events is essential, and Sandia researchers are enhancing that capability by developing a microsystem-based launch environment detection device that operates without any net power. This innovative approach leads to a drastic reduction in size compared to legacy devices, making it easier to integrate into various systems. The team's microsystem-based devices are highly configurable, eliminating the need for redesign with each new application.

The potential benefits of this work extend to critical mission spaces, particularly in nuclear deterrence applications. By enhancing detection capabilities, Sandia researchers contribute to national security and strategic stability.

Looking ahead, the team has planned follow-on projects focused on technical maturation through future R&D. This ongoing effort will help ensure the technology is ready for the next insertion opportunity, further advancing Sandia's commitment to innovation and excellence in defense applications. (PI: Brian Homeijer)

Strengthening computing infrastructure against radiation vulnerabilities

As major companies like TSMC, Intel, and Samsung transition to Gate-All-Around Field Effect Transistors (GAA-FET) technology, adversaries are intensifying their efforts to take advantage of potential vulnerabilities in computing resources and infrastructure in space applications. In response, Sandia researchers are collaborating with IBM to evaluate the resilience and reliability of GAA-FET transistors and circuits when exposed to radiation and also comparing GAA-FET performance to previous technologies and proposing mitigation strategies.

The team investigated how circuit speed changes under ionizing radiation and neutron exposure, utilizing a Sandia-developed modeling package to analyze the quantum effects on transistor characteristics and ring oscillator circuits.

Preliminary results indicate that, without radiation hardening, GAA-FETs and their ring oscillator circuits outperform many commercially available transistors under Total Ionizing Dose exposure. However, there is a slight reduction in operating frequency in certain regimes due to charged defects.

To further the work of this LDRD project, Sandia proposed a collaboration with IBM to fabricate Sandia-designed circuits at IBM Albany Nanotech facilities, aiming to enhance reliability and reduce soft-error rates in critical computing applications. To date, the project has resulted in five invited/contributed conference presentations.
(PI: Reza Arghavani)

READ MORE > *ACS Applied Electronic Materials*

Reducing the cycle time from design to simulation in nuclear deterrence analysis

Converting CAD models into input for numerical simulation is a significant bottleneck in nuclear-deterrence analysis, so a Sandia LDRD team is developing a fully automated algorithm that generates adaptive, high-quality, anisotropic meshes with theoretical guarantees. This innovative solution will be a game changer for many applications at Sandia, drastically reducing the design-to-simulate cycle and enhancing confidence in parallel meshing.

The new methodology will automatically detect and remove unwanted features, providing correctness proofs and guaranteed mesh quality. An open-source implementation of this robust, Delaunay-based meshing algorithm will empower industries to create better and safer products. Sandia researchers are collaborating with the Next-Generation Simulation Development geometry and meshing teams to integrate this technology into production tools.

Key contributors to this project include Nick Winovich, Liam Moynihan, Jeff Sharpe, and Riley Price, all of whom joined Sandia through this initiative. The team plans to submit a research paper to the upcoming SIGGRAPH conference and has follow-on projects to extend the meshing algorithm for more complex applications. (PI: Mohamed Ebeida)

Teams at Sandia are developing advanced concepts, technology, and materials to make the W80-4 warhead one of the safest and most secure systems in the U.S. nuclear stockpile.

Breaking legacy radio frequency sensing limits

Sandia Wide Aperture Radar Magnifique (SWARM) aims to revolutionize intelligence, surveillance, and reconnaissance (ISR) sensing by distributing a large antenna aperture across numerous small airborne swarm platforms (see Figure). This innovative approach overcomes the size, weight, and power constraints of traditional methods and introduces groundbreaking RF sensing capabilities, including:

1. Distributed real-aperture radar: Enables real-time imaging of moving targets while reducing sensor costs.
2. Distributed RF beam synthesis: Allows elements or sub-arrays of the swarm aperture to remain in motion.
3. Distributed relative localization, navigation, and guidance algorithms: Facilitates autonomous formation control.

SWARM, done in collaboration with Sandia National/Regional partner New Mexico Tech (NM Tech) Professor Aly El-Osery, paves the way for novel applications requiring structured illumination, spatial modulation, and high equivalent isotropic radiated power/ receiver sensitivity. Inspired by nature and driven by the goal of establishing a superior RF sensing paradigm, future work aims to ensure uncontestable ISR and RF dominance on the battlefield across all domains for the U.S. in the coming decade and beyond through collective action. (PI: Jacques Loui)

COOL FACT > SWARM's advancements are crucial for navigation in GPS-denied environments, secure communications, and both offensive and defensive RF countermeasures.

LEVERAGING NEW TALENT > NM Tech students Eryn Jaramillo, Xander Jones, and Nicolas Ali developed innovative estimation algorithms that enhanced the accuracy and precision of cooperative navigation solutions for airborne swarms. Their research was presented at the Pacific Positioning Navigation and Timing conference in 2024 and led to the successful completion of Jaramillo and Jones' master's degrees.

Legacy ISR limits sensor size to the platform; SWARM allows sensors to be as large as needed.

LDRD PI Jacques Loui is leading a team developing Sandia Wide Aperture Radar Magnifique (SWARM), which aims to revolutionize intelligence, surveillance, and reconnaissance (ISR) sensing. (Photo by Craig Fritz)

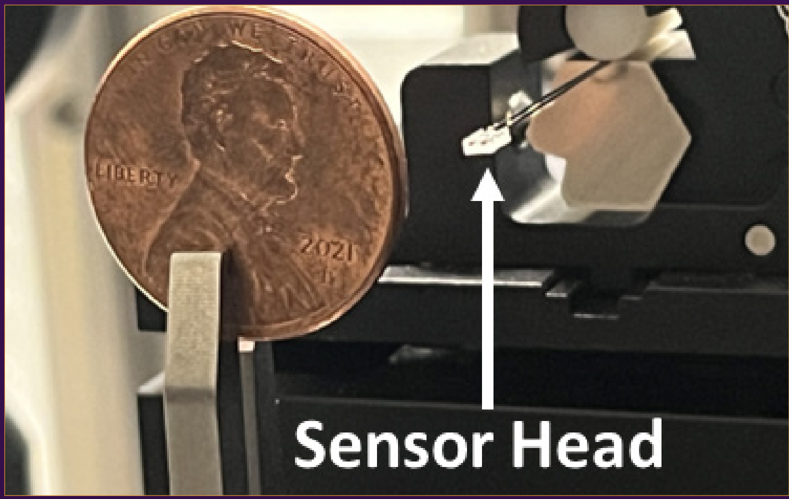
Enabling 3D imaging in denied access areas through miniaturized borescope design

Within structurally denied environments, where access points are often less than one millimeter, 3D imaging is almost impossible. To overcome this limitation, the team has developed a groundbreaking 3D imaging borescope featuring a novel sensor head design that was enabled through innovative implementation of beam steering metasurface lenses. This advancement enabled miniaturization of the borescope sensor head to under one millimeter which allows for effective imaging in spaces that were previously inaccessible.

This work has significant implications for mission spaces within Sandia, enhancing operational capabilities in complex environments. Looking ahead, Sandia researchers plan to implement visible light operation using titanium dioxide metasurface lenses to achieve optimal imaging results. This ongoing research promises to further advance the field of imaging technology and expand its applications. (PI: Zachary Piontkowski)

COOL FACT > This novel sensor head design represents a tenfold improvement over existing technologies.

LEVERAGING NEW TALENT > Key contributors to this project include postdoc William Delmas.



The compact three-dimensional imaging borescope sensor head, displayed alongside a penny for scale.

Accelerating scientific discovery with sub-100 picosecond neutron detection

The energy of neutrons can be measured by how long it takes from when they are produced to when a signal is picked up by a detector, known as "time of flight." Currently, neutron time of flight measurements are hindered by slow instrument response times. At Sandia, an LDRD team has developed an innovative neutron time of flight test chip that achieves a simulated temporal resolution of less than 100 picoseconds.

This novel detector concept can be utilized in facilities conducting Inertial Confinement Fusion and High Energy Density (HED) physics research, such as the Z-machine at Sandia and the National Ignition Facility at Lawrence Livermore National Laboratory. Sandia is dedicated to advancing scientific research and improving measurement techniques that are essential for exploring complex physical phenomena. (PI: Nathan Paul Young)

COOL FACT > By providing a foundational technology for advanced diagnostics, this new neutron detector will significantly enhance the capabilities of the HED physics community.

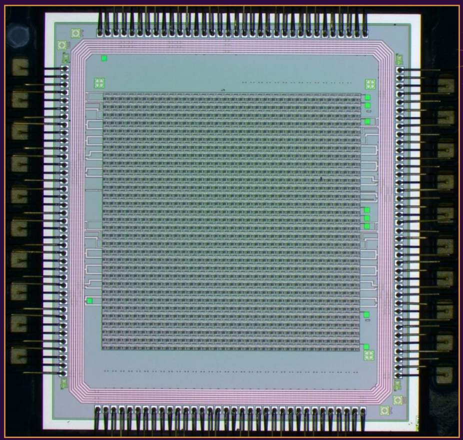


Image of the innovative neutron time of flight test chip created by Sandia researchers.

Driving innovation in chemical warfare sensor technologies

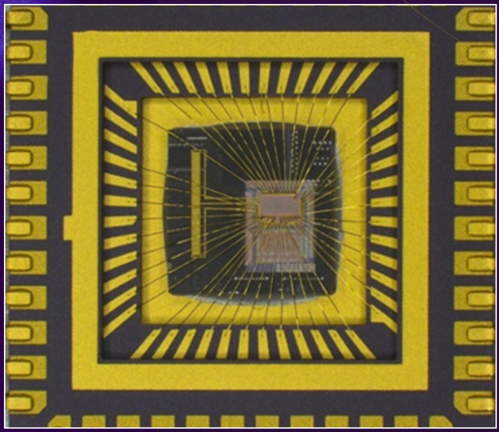
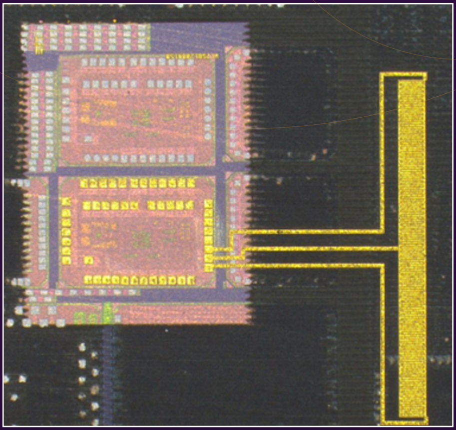
Sandia researchers have successfully tackled designing, manufacturing, and testing a cutting-edge chemical warfare sensor featuring a low-power readout circuit operating in the nanowatt range. This innovative sensor utilizes a readout integrated circuit built with advanced 65-Nm technology from Taiwan Semiconductor Manufacturing Company, developed using multi-project wafers (MPW).

Sandia researchers optimized the sensor's performance by refining spraying and curing protocols for sol-gel on gold electrodes, enabling rapid detection of chemical warfare agents. The team also developed advanced techniques to minimize the sensor's size using novel integration of MPW die while ensuring reliable connections between the readout integrated circuit and the electrodes.

This work, done in collaboration with the University of Virginia, not only presents a novel method for constructing a low-SWaP sensor but also offers a transferable approach for developing low-power sensors across various applications. Findings were shared through publications and presentations through IEEE and AVS. Follow-on projects are already underway to further leverage this technology. (PI: Mieko Hirabayashi)

COOL FACT > This novel sensor head design represents a tenfold improvement over existing technologies.

LEVERAGING NEW TALENT > Key contributors to this project include postdoc William Delmas.

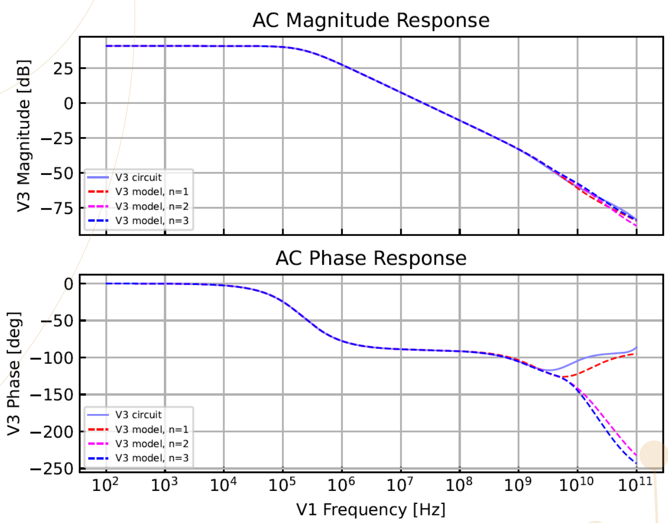
Left: Packaged and wirebonded sensor. Right: Close up image of sensor built on top of read out circuit.

Utilizing reduced-order models of physical systems for accelerated design of electrical systems

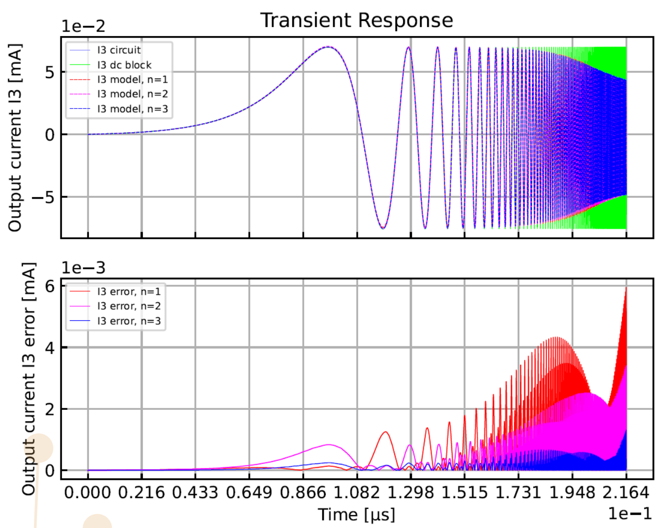
Sandia demonstrated identification of state-space systems as a promising, non-intrusive model order reduction (MOR) alternative to existing approaches, applicable to both circuits and devices. The LDRD team developed novel device-level MORs that effectively model combined radiation effects, maintaining accuracy across wide ranges of operational and environmental conditions. MORs for amplifier and comparator circuits, based on novel sequential parameter identification of Hammerstein-Wiener architectures, accurately capture circuits behavior, and exhibit favorable scalability.
(PI: Biliana Paskaleva)

READ MORE > *IEEE Transactions on Nuclear Science*, *Earth and Space 2022*, *Journal of Hardware and Systems Security*, *Foundations of Data Science*, *Cryptography*, *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*

LEVERAGING NEW TALENT > Sandia Alliance partner University of New Mexico explored MOR for design of physically unclonable functions for hardware security, which contributed to the completion of the PhD dissertation for Jenilee Jao and the advancement of the PhD dissertations for Ian Wilcox. This LDRD also fostered collaboration with the Alliance partner University of Illinois Urbana-Champaign and National/Regional partner University of Arizona, leading to the hires of postdoctoral researcher Joshua Hanson and graduate interns Ethan Thieme and Teddy Meissner.



Gain (top plot) and phase responses (bottom plot) between Xyce simulation of a differential amplifier circuit and the Hammerstein model.



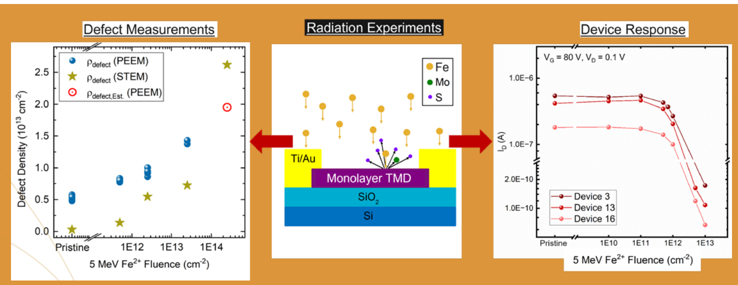
Top: Transient output currents computed by the Hammerstein differential amplifier model and Xyce simulation. Bottom: Simulation error of the Hammerstein differential amplifier model.

Unlocking enhanced radiation tolerance in 2D electronics

By investigating radiation effects in 2D-transition metal dichalcogenides (TMD), Sandia researchers are addressing a critical challenge in the development of next-generation radiation-hard electronics. Monolayer TMDs exhibit a significantly reduced interaction cross section with radiation, making them promising candidates for radiation-tolerant devices. However, material properties that contribute to enhanced radiation tolerance in certain TMDs remain unclear, which could be used as a template to identify the most radiation tolerant 2D materials for technology.

The team combines ion beam experiments, modeling, and machine learning to explore how radiation response varies across TMD compositions. An innovative technique has also been developed to quantify defects in TMDs at low concentrations, which is crucial for diagnosing failures in irradiated TMD devices. Ultimately, this research, done in collaboration with Alliance partner University of New Mexico, will identify the best TMDs for rad-hard electronics, demonstrating their potential for mission applications in harsh environments.

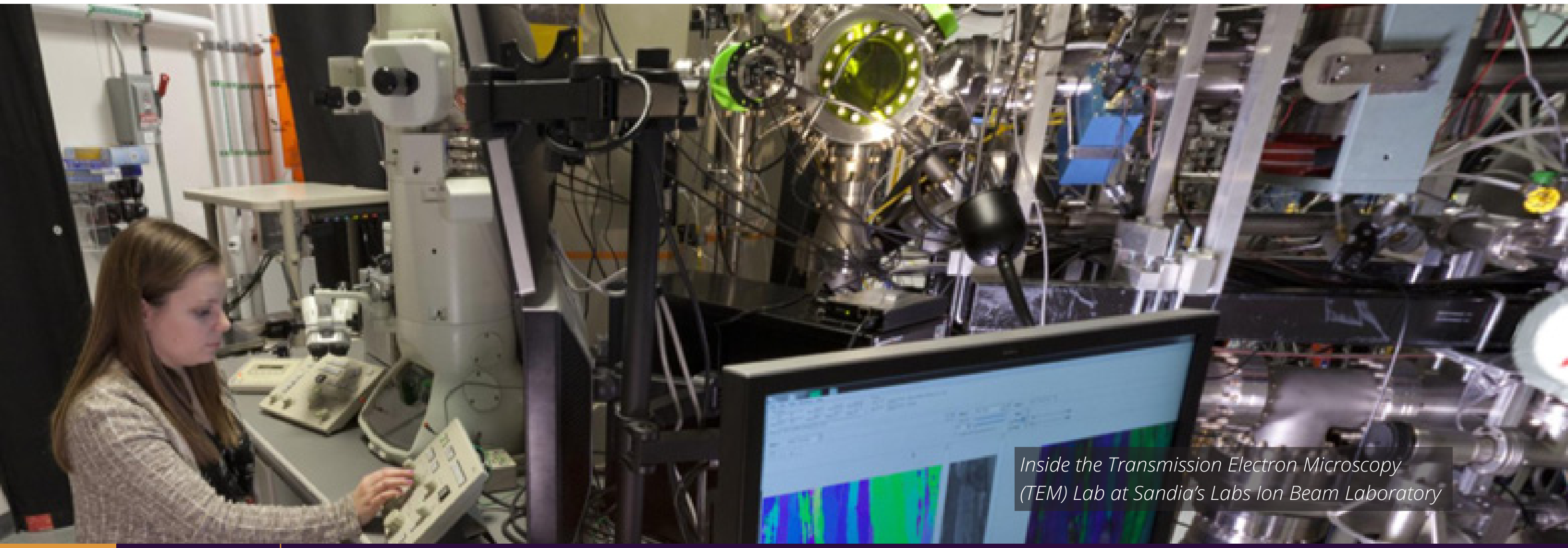
Sandia researchers have published significant findings, generated intellectual property, and presented at conferences, showcasing the high impact of their results. Through collaborations with commercial partners and follow-on funding, they aim to advance this promising technology. (PI: Chris Smyth)



Using ion beam irradiation, researchers developed techniques to measure defects and study radiation impacts on TMD films.

LEVERAGING NEW TALENT >

- Mark Reymatias, a graduate student intern at the Center for Integrated Nanotechnologies, performed MoS2 device fabrication and in-situ ion irradiation experiments.
- Sydney Brown, an undergraduate student intern, is working on fabricating an all-two-dimensional material bipolar junction transistor and evaluating its performance under ion irradiation.
- In the summer of 2025, graduate student Michael Curtis will test the heavy ion irradiation response of chemical vapor deposition-grown 2D material devices at the Sandia Ion Beam Laboratory.



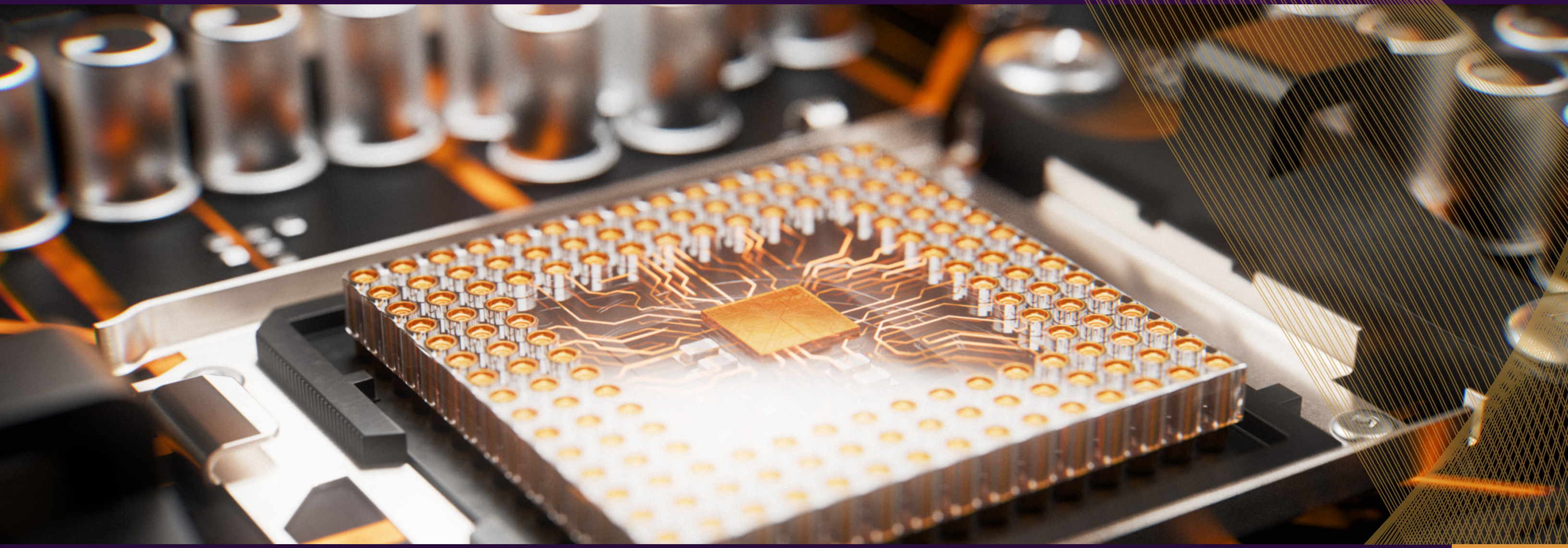
Inside the Transmission Electron Microscopy (TEM) Lab at Sandia's Labs Ion Beam Laboratory

Radioimaging for real-time tracking of high-voltage breakdown

Radioimaging, developed over three years as part of an LDRD project, aims to screen for early failures in electrical components by detecting corona discharge and arc discharge within a 250 kHz - 2.5 GHz bandwidth. In collaboration with Sandia Alliance partner University of New Mexico, the project demonstrated that radioimaging can effectively locate high voltage breakdown (HVB) events in real-time, both internally and externally, with high fidelity—unlike existing non-destructive diagnostics that lack resolution or only detect external breakdowns.

This technology has already benefited industry clients, including MESA and TPL Inc., and received the NNSA's Defense Programs Award of Excellence in 2022 for technology transfer of radioimaging for detection of dielectric breakdown in commercial capacitors. Radioimaging is gaining traction as a validation tool for HVB modeling due to its high fidelity in depicting HVB dynamics and has secured follow-on funding for DOE and nuclear deterrence projects in FY25-26. (PI: Julia Tiles)

LEVERAGING NEW TALENT > Torin Sammeth, a master's student in electrical & computer engineering at Sandia Alliance partner University of New Mexico, performed experimental research on corona discharge radiofrequency emissions, conducted analysis, and coauthored the final report for the project.



Enhancing infrastructure resilience using advanced modeling methods

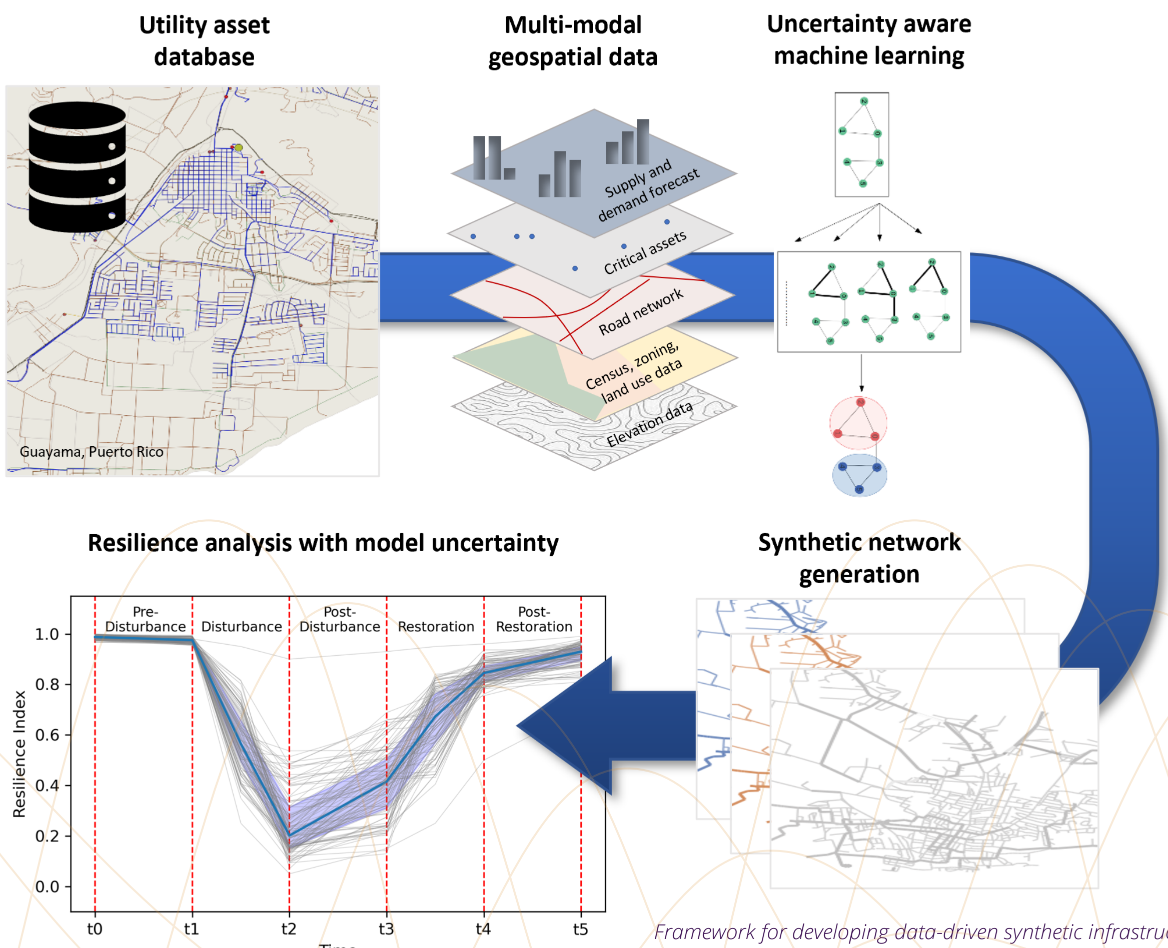
Infrastructure must be resilient to disasters and hazards throughout its lifecycle, so Sandia researchers are developing novel approaches to assess the durability of facilities and their ability to recover rapidly from disruption. Traditional analysis methods rely on detailed models of infrastructure systems, but data sharing restrictions and high model development costs limit their use. In addition, many utilities have proprietary models that are inaccessible for research and can quickly become outdated after disruptions.

To overcome this, Sandia, in collaboration with National/Regional partner Arizona State and Oregon State University, is creating synthetic infrastructure models using diverse datasets, focusing on power and drinking water systems in Puerto Rico. By integrating sparse utility data, geospatial information, and machine learning, the team is generating models that can adapt to changing conditions.

The results will provide essential capabilities for utilities and researchers, facilitating resilience analysis and investment decisions for Puerto Rico and other regions and domains. (PI: Kate Klise)

READ MORE > *Water*

COOL FACT > This project bridges the gap between resilience research and real-world application, ensuring communities are better prepared for future challenges.



Framework for developing data-driven synthetic infrastructure models for resilience analysis.

Strengthening infrastructure security through emulated zero-trust environments

The risks to the nation's infrastructure are changing swiftly, as operational technology systems, protocols, and devices face growing attention from attackers. There is an urgent need for enhanced cybersecurity measures, especially in industrial control systems where availability is critical, and while federal agencies have been directed to adopt a zero-trust architecture to strengthen cybersecurity, limited research exists on its application in these environments.

Sandia's TADDA-RES project aims to improve the security of critical infrastructure by developing an emulated environment where zero-trust architecture can be implemented using software-defined networking for intelligent access control. This LDRD team created a nuclear plant model with an emulated software-defined networking controller that modifies data flow based on threat alerts, enabling practical testing of cybersecurity mitigations.

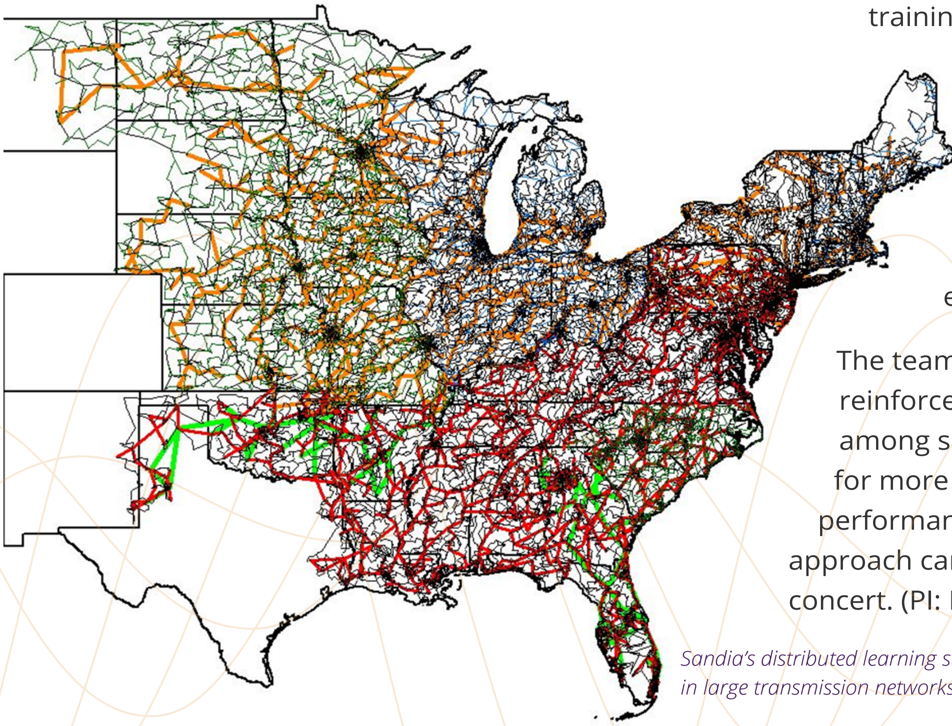
Many challenges remain to implement true zero trust in real-world applications, but, if successful, the data from the emulations in this project could provide a proof of concept for zero trust in industrial control systems. (PI: Amanda Gonzales)

Using distributed learning agents to strengthen resilience of agents' infrastructure

Recent threats to power systems highlight the urgent need for dynamic response capabilities. In response, LDRD researchers are creating robust controllers capable of managing the complexities of real-world power transmission networks, ultimately enhancing infrastructure resilience against emerging threats.

Sandia is developing advanced reinforcement learning controllers to enhance the resilience of power transmission systems. Traditional optimization methods struggle with the complex dynamics of these systems, especially as they scale beyond 100 buses, so this research aims to implement innovative techniques to improve the training and efficiency of reinforcement learning models. This includes parallelizing training processes to run multiple simulations simultaneously, simplifying models to focus on key components, and augmenting training data to enhance learning.

The team is also using multi-agent reinforcement learning to distribute control among several independent agents, allowing for more manageable learning and improved performance. Initial results show that this approach can train teams of agents to operate in concert. (PI: Drew Levin)



Sandia's distributed learning strategy helps maintain optimal performance in large transmission networks during potential interruptions.

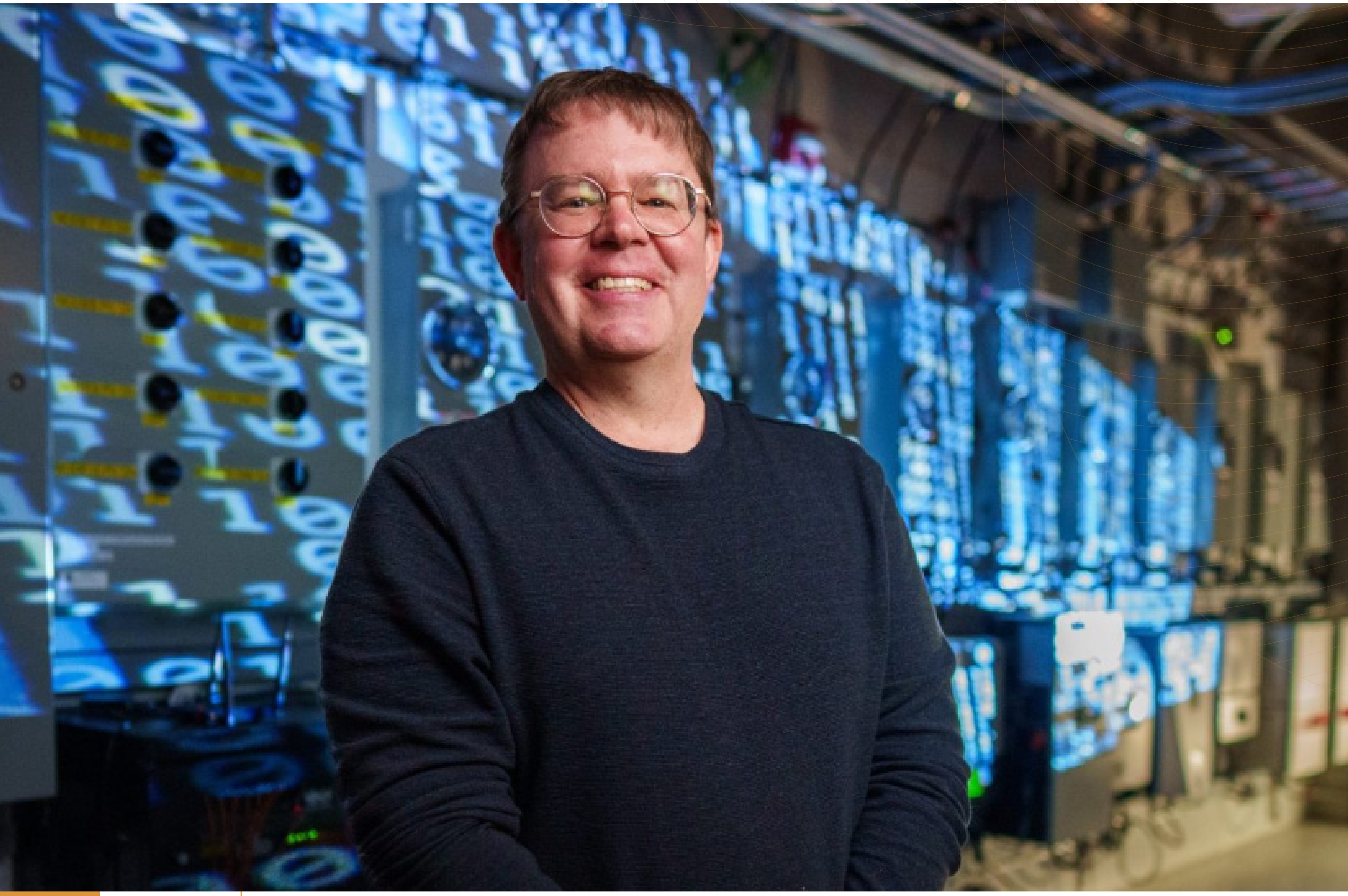
Protecting power systems by understanding more about synchronous condensers

Enhancing resilient energy systems, protecting essential infrastructure, and supporting defense applications is critical for the nation. One way Sandia is supporting these missions is by improving the fundamental understanding of synchronous condensers in inverter-energized self-healing microgrids. These systems have low fault current and low inertia, which can impact their dynamic performance and protection. Synchronous condensers are often mentioned as a promising, potentially low-cost solution to these issues.

The Sandia research team found that in these systems, synchronous condensers provide some of the expected benefits, but not all. They also identified there is a critical clearing time associated with synchronous condensers, and that the size of the synchronous condensers needed in inverter-energized microgrids is significantly larger than conventional wisdom suggests, which raises cost challenges.

Looking ahead, Sandia plans to integrate these findings into Sandia's Self-Healing Power Systems Toolbox for further development and application. The team is preparing papers for publication at IEEE Power and Energy Society conferences. (PI: Michael Ropp)

Sandia electrical engineer Michael Ropp and his team have created a library of codes to improve the resilience, reliability, and self-healing nature of the electric grid. (Photo by Craig Fritz)



Reducing costs by efficiently regulating heat in space applications

In space, radiation is the only way to transfer heat, and current thermal regulation technologies often add significant size, weight, and power demands to spaceborne assets. Sandia researchers have developed an innovative solution: an inexpensive, lightweight, and conformal thermochromic nanocomposite coating.

This groundbreaking technology uses vanadium dioxide nanoparticles that change from insulating to metallic at higher temperatures, enhancing heat radiation. The team created a unique sequential deposition method to integrate these polar nanoparticles into inert polymeric materials, achieving uniform and large-area coatings without the need for chemical modification.

These nanocomposites exhibit remarkable temperature-dependent emissivity switching, along with excellent scalability, adhesion, and stability. The project has involved contributions from postdoctoral researchers and graduate students, and is now expanding into other application areas, highlighting Sandia's commitment to advancing thermal management solutions for space and beyond. (PI: John Kenneth Grey)

COOL FACT > The thermochromic nanocomposite coating enables passive radiative cooling without relying on electrical or mechanical systems, ultimately reducing cooling costs.

LEVERAGING NEW TALENT > Postdoc Simi Grewal was engaged for this project and presented on nanocomposite films at the Center for Integrated Nanotechnologies.

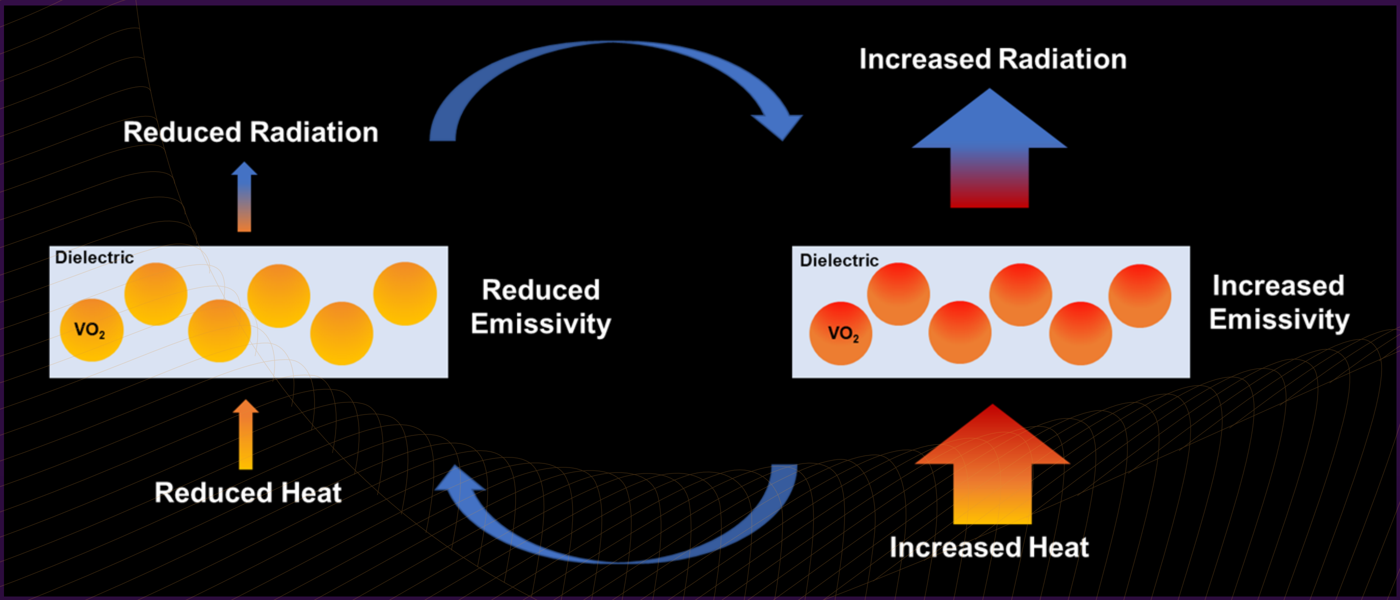


Illustration of thermochromic nanocomposite function, enhancing heat radiation for stable temperature control.

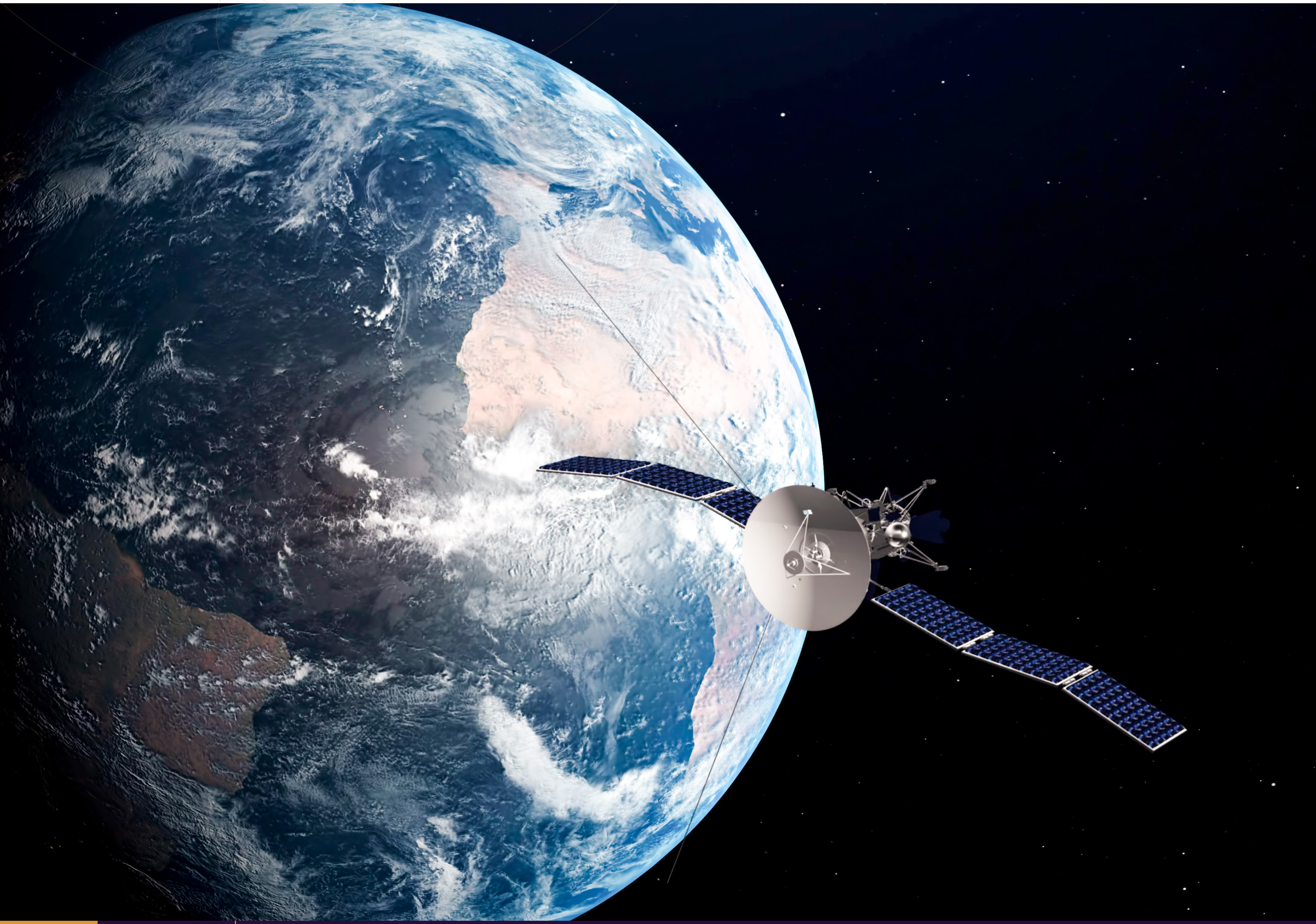
Detecting and understanding anomalies in satellite health in real time

Identifying unexpected behaviors in satellite health telemetry can be difficult due to the vast number of sensors and the diverse data types. Operational constraints and the need for timely responses to both natural and human-induced disruptions further complicate this task.

To tackle these challenges, Sandia researchers developed a machine learning analytic that leverages the flexibility of k-means clustering (partitioning datasets into distinct groups based on feature similarity) with the efficiency of streaming algorithms. This enables real-time anomaly detection of both rare individual events and clusters of unusual activity, even in resource-constrained environments. This advancement not only enhances operational resilience but also prepares Sandia for future challenges in an increasingly complex space environment.

Sandia researchers have presented their work at conferences, highlighting the potential applications of this technology to space and to other edge systems. (PI: Justin Li)

COOL FACT > This research can improve automation for real-time monitoring of satellite operations both in-flight and on the ground.



Sandia's innovative edge-computing platform withstands harsh radiation while managing high data throughput and complex calculations.

Revolutionizing high-speed data processing for extreme environments

Sandia researchers are creating a stable and robust hardware solution to serve space computing applications for decades to come. This state-of-the-art edge computing platform is designed to manage high data throughput, perform complex calculations, and execute autonomous decision-making algorithms, all while withstanding harsh radiation environments such as space.

Recently, the team showcased their findings through poster presentations at the Small Satellite Conference, highlighting the importance of this work. By advancing edge computing technology, Sandia is ensuring that critical data can be processed efficiently and reliably in challenging environments paving the way for future space exploration and for integration into other high-demand applications. (PI: Scott Strathman)

COOL FACT > This hardware solution not only enhances the capabilities of space missions but also has the potential to be applied in any field requiring high-speed data processing.

Protecting global monitoring systems against high-energy laser risks

High-energy lasers pose real threats to sensors, and a Sandia LDRD team is developing an innovative solution to the problem. Their research aims to create autonomous protection systems that can reduce the intensity of high-energy lasers, preventing damage or dazzling of imaging sensors.

Researchers shared findings through a paper submitted to the *Journal of Vacuum Science and Technology B* and presented at the Conference on Lasers and Electro Optics. The potential applications of this work extend to space-based global monitoring systems, supporting the STARCS Mission Campaign. This initiative aims to implement these protective technologies in relevant space-based systems, enhancing the safety and effectiveness of critical sensors in challenging environments. (PI: Amun Jarzembski)

LEVERAGING NEW TALENT > Chloe Doiron, who transitioned to a staff member at the Center for Integrated Nanotechnologies, and William Delmas, who is now with the Kansas City National Security Campus, were both instrumental in advancing this project.

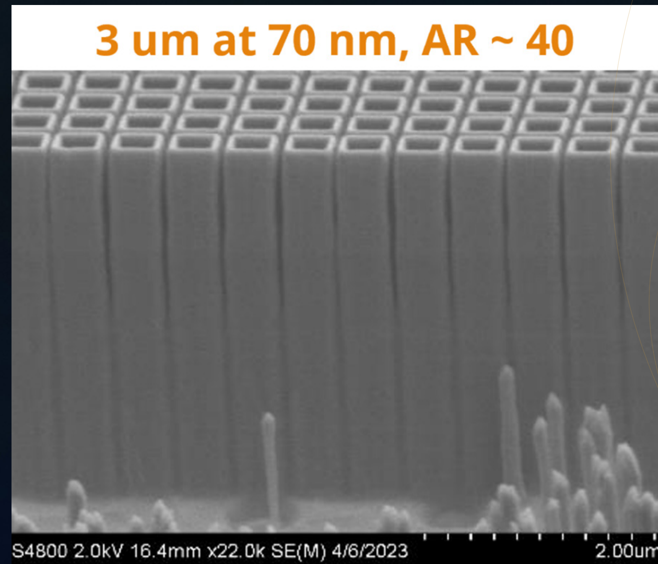


Figure 1: Metaoptic structure with 70 nanometer features, etched 3 μm into silicon for advanced applications.

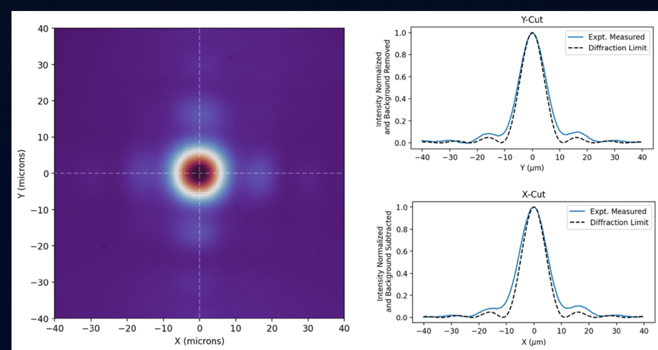


Figure 2: Performance of the metaoptic structure measured and compared to diffraction theory expectations.

Computing reconfiguration for resilient space platforms (CRRSP)

Heterogeneous computing platforms (HCP) are being explored by Sandia for their potential to enhance computational resilience. HCP may offer a unique opportunity for resilient execution, which ensures that systems can continue functioning even in the face of malicious attacks.

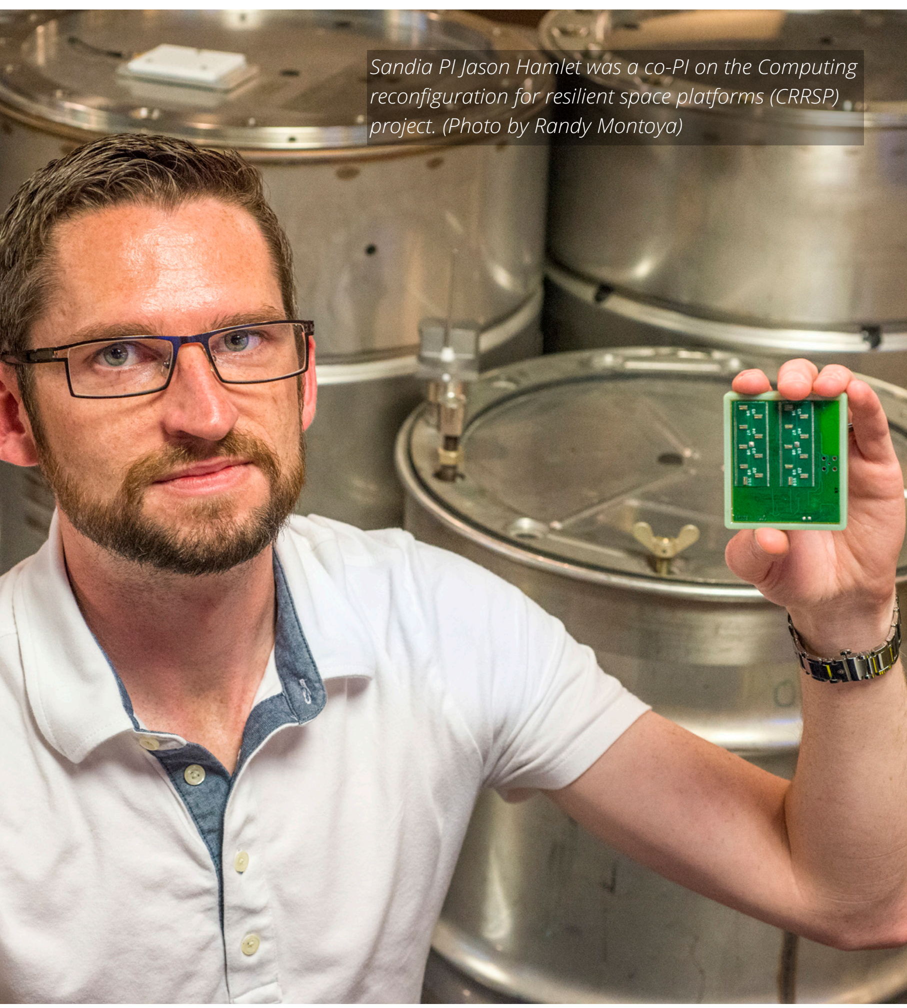
This LDRD team has developed a comprehensive taxonomy, conducted simulations, and performed experiments to support this research. They simulated various attacks and compared the performance metrics of three approaches: CRRSP, triple modular redundancy, and dual modular redundancy.

Findings indicate that the CRRSP approach provides greater resilience than both triple and dual modular redundancy, although it requires a more complex programming model. Sandia researchers collaborated with Bharat Bhargava from Purdue; the university developed a mathematical model and conducted simulations to compare with Sandia's internal experiments. (PIs: Chris Jenkins, Jason Hamlet)

COOL FACT > Sandia's CRRSP approach is vital for high-consequence systems, safety systems, space systems, traffic systems, and any environment where faults could result in significant harm to individuals.

LEVERAGING NEW TALENT > Josh Mayhugh and Bethanie Williams conducted tests on the versal boards and analyzed the results from those experiments and from Purdue's simulations.

CRRSP
Computing Reconfiguration for Resilient Space Platforms



Sandia PI Jason Hamlet was a co-PI on the Computing reconfiguration for resilient space platforms (CRRSP) project. (Photo by Randy Montoya)

Sandia cybersecurity expert Chris Jenkins was one of the PIs helping to lead the Computing reconfiguration for resilient space platforms (CRRSP) project. (Photo by Craig Fritz)

PROJECT HIGHLIGHTS –

TECHNICAL VITALITY

LDRD is essential to maintaining the Labs' scientific vitality, and Sandia, as the nation's most diverse national security laboratory, is uniquely equipped to tackle groundbreaking, interdisciplinary research. Researchers collaborate across a broad spectrum of disciplines and achieve research breakthroughs, which enables national security technology to be transferred to industry, commercialized under licensing agreements, and brought to market for the U.S. public good.

The LDRD accomplishments in this section highlight research outcomes that significantly extend knowledge in the scientific field or have the potential to provide a new capability for Sandia in the future.

Accelerating energy independence through optimized fungal biomanufacturing

Optimizing biomanufacturing fungi is essential for a sustainable economy and national security, so a Sandia team discovered a way to harness specific properties from diverse fungi on demand without disrupting their functions.

To achieve this, Sandia developed a machine learning algorithm called Evolutionary distance Adaptable Gene expression Learned from Epigenomics (EAGLE), which predicts gene expression modifications across species. They also created Poplar, software that analyzes evolutionary distances between fungi, enhancing EAGLE's capabilities.

Collaborating with experts like Omoanghe Isikhuemhen at Sandia Securing Top Academic Research & Talent at HBCUs partner North Carolina A&T and Julian Chen from National/Regional partner Arizona State University, researchers have generated valuable data and shown the ability to modify gene expression in various fungi relevant for biomanufacturing, from yeasts to filamentous species. This work reduces experimentation needed to integrate novel fungi into biomanufacturing.

Sandia is preparing to submit manuscripts for EAGLE and Poplar and seeking follow-on funding to expand this research. (PI: Raga Krishnakumar)

READ MORE > *Biology* (*preprint 1*) (*preprint 2*)

COOL FACT > Applications for EAGLE and Poplar span manufacturing, energy independence, and defense against pathogens, paving the way for a sustainable future.

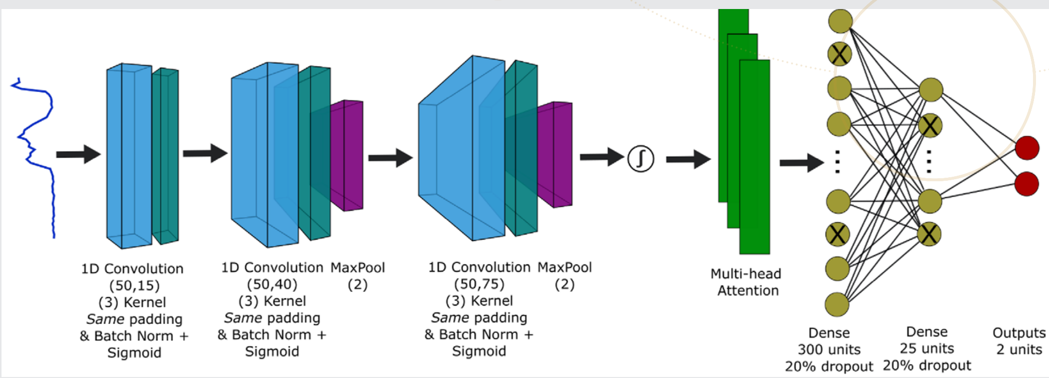


Figure 1 - EAGLE model processes sequence data from epigenetic markers using multiple convolutional layers and attention networks.

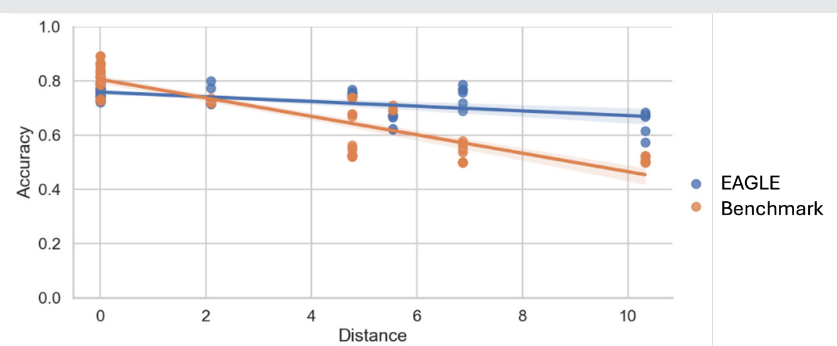


Figure 2 - EAGLE maintains better accuracy than the benchmark model across varying evolutionary distances, as shown in the scatterplot.

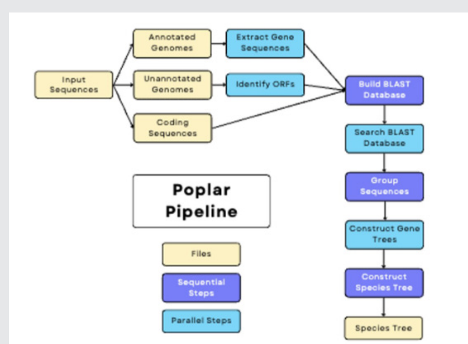
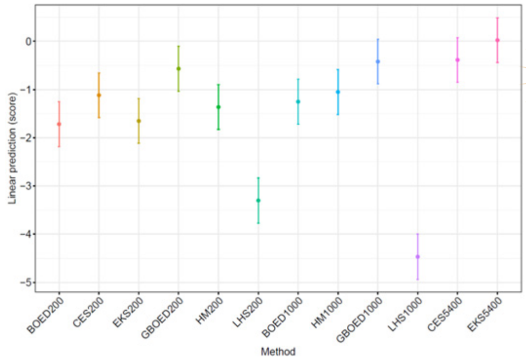


Figure 3 - Poplar pipeline is user-friendly software for constructing species trees from both annotated and unannotated genome sequences.

Accelerating science through goal-oriented simulations

Calibrating complex physics models like the Energy Exascale Earth Systems Model (E3SM) is too computationally expensive to run extensively, so Sandia researchers developed Bayesian Optimal Experimental Design (OED) methods that strategically select the most informative simulations for calibration, addressing model discrepancies and uncertainties while offering advantages for chaotic systems.

Applications extend to nuclear monitoring, where OED improves sensor placement, and materials testing, where it optimizes simulations and experiments of novel materials and components. Collaborations with the University of Michigan and Stanford interns contributed to this effort. Research has been published and presented through Society of Industrial and Applied Mathematics and Institute of Electrical and Electronics Engineers.



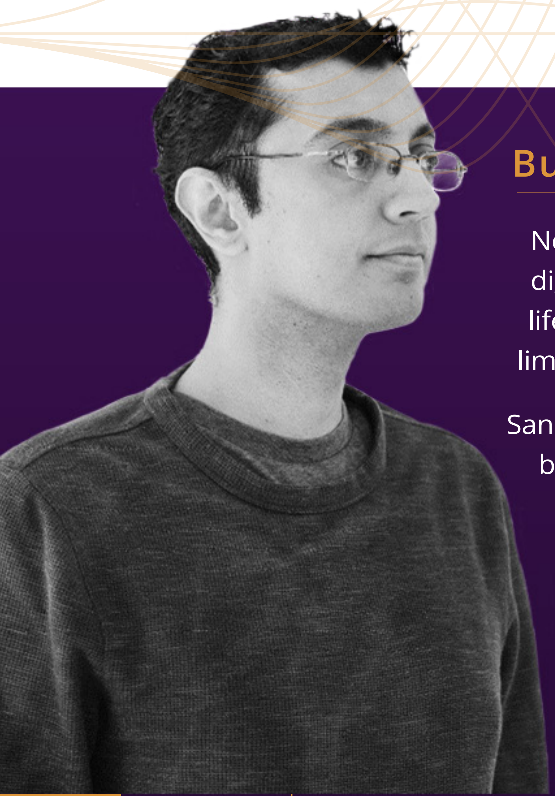
Sandia's GB-OED method achieves higher scores with fewer simulations, ideal for fitting models under constrained computational resources.

Future efforts include integrating robust OED into Sandia's Advanced Scientific Computing Research program, advancing autonomous discovery, and collaborating with E3SM teams on future models. (PI: Tommie Catanach)

READ MORE > *arXiv*, *IEEE Xplore*

COOL FACT > The Goal Oriented-OED (GB-OED) method accelerates data analysis and improves predictions and decision-making within computational budgets.

LEVERAGING NEW TALENT > Several postdocs, including Maike Holthuijzen and Niladri Das, were key contributors to this work. Through Sandia's partnership with University of Michigan, Atlanta Chakraborty contributed, as did Felix Meng and Peranut Nimitsurachat from the Stanford ICME Xplore program, and Sandia year-around intern Anuj Shetty.



Building efficient neuromorphic systems

Neuromorphic hardware presents a promising alternative to traditional digital computers, which are approaching the end of their operational lifespan. However, its competitiveness is hindered by two critical limitations: a lack of reconfigurability and insufficient training methods.

Sandia has made significant strides in addressing these challenges by drawing inspiration from biological brains to develop efficient neuromorphic systems. They have created models of artificial neurons and synapses capable of predicting desired material properties for specific behaviors, successfully isolating the edge of chaos to enhance performance. This approach has led to the construction of metal lines

Sandia LDRD PI Suhas Kumar led a project team focused on building efficient neuromorphic systems.

Accelerating material discovery for optimal photonic materials

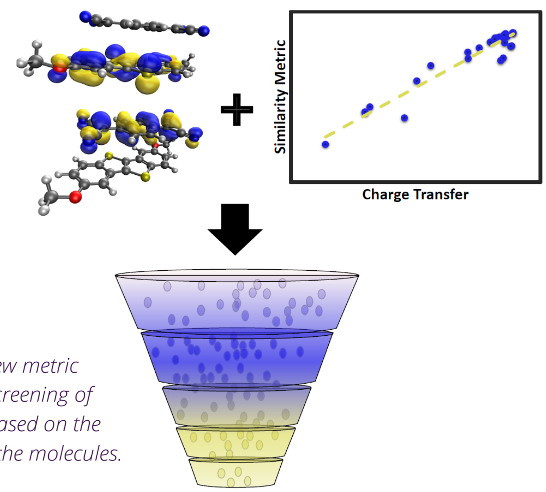
Sandia researchers have made significant strides in developing new structure-property relationships for donor-acceptor co-crystals, essential for next-generation optoelectronic devices in integrated photonics and crucial for building compact quantum computers.

LDRD PI Laura McCaslin led a project team with a goal of accelerating material discovery for optimal photonic materials.

To correlate the properties of the component molecules with the optical properties of the materials, the team employed ab initio molecular dynamics and transient absorption spectroscopy. The new relationships can predict how long a molecular crystal remains photoexcited based on its electronic structure, enhancing future machine learning protocols for identifying optimal photonic materials. Key external contributions came from Professor John Herbert at Ohio State and Professor Marissa Weichman's group at Princeton. Looking ahead, the team plans to integrate these design principles into high- throughput screening processes, accelerating the rate of materials discovery. (PI: Laura M. McCaslin)

READ MORE > *The Journal of Physical Chemistry Letters*

LEVERAGING NEW TALENT > Postdocs Ali Abou Taka, Joseph Reynolds, Mohana Shivanna, Savini Bandaranayake and intern Christine Yu were instrumental to the success of the project.



Sandia developed a new metric for high-throughput screening of molecular materials based on the electronic densities of the molecules.

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that can amplify their own signals, akin to axons, and has demonstrated the ability to train groups of neuron-like devices as well as fully reconfigure individual devices.

The DOE neuromorphic co-design efforts have recognized the importance of reconfigurability and training algorithms, which were positively received at the Basic Research Needs workshop of DOE/Advanced Scientific Computing Research and are expected to be included in future DOE/Office of Science funding opportunity announcements. (PI: Suhas Kumar)

READ MORE > *Physical Review Applied*, *Nature Electronics*, *ACS Nano*, *Nature*

COOL FACT > Sandia has emerged as a leader in three key neuromorphic sub-areas: data movement, reconfigurability, and training, achieving computing efficiencies that surpass traditional digital computers by over 10,000 times.

LEVERAGING NEW TALENT > Postdoc Timothy David Brown supported this LDRD project.

Enhancing pulsed power machines by understanding how ions affect magnetically insulated electron flows

Sandia researchers have tackled a complex challenge in understanding how ions influence electron flow in magnetically insulated transmission lines. During the research, the team discovered that traditional theoretical methods overlooked a crucial electron-ion interaction, necessitating innovative approaches to resolve this issue.

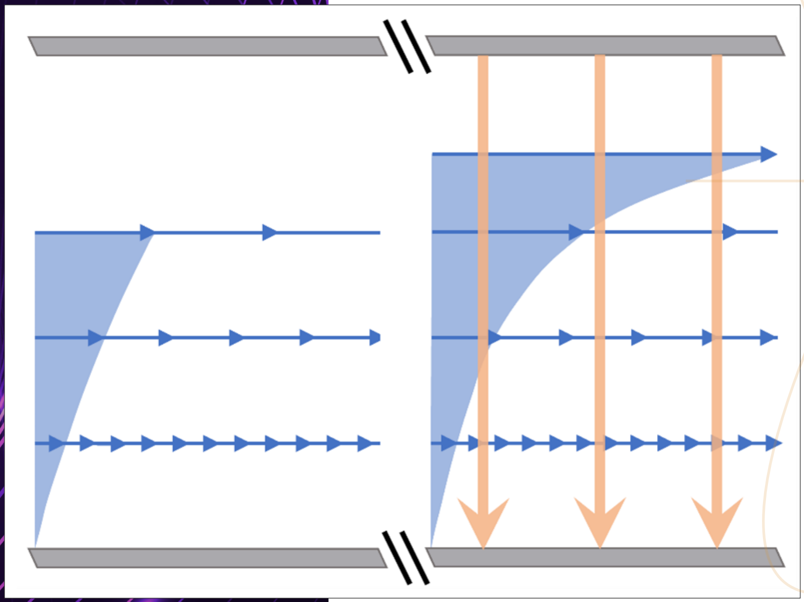
The results improve understanding of how ions affect magnetically insulated electron flows. When ions are present, electron currents can increase dramatically with stronger magnetic fields—potentially up to 10,000 times more than electron only theory, which predicts the opposite trend. Additionally, when ions flow freely through the electrons, they cause the electron layer to expand, leading to operational risks such as gap shorting.

This research, supported by diverse mentorship and contributions from undergraduate interns, has been recognized in prestigious publications and conferences. Follow-on projects are planned to enhance Sandia's existing and next-generation pulsed power machines. (PI: Adam Darr)

READ MORE > *Physics of Plasmas*, *Physical Review Letters*

COOL FACT > The findings of this project hold promise for advancing pulsed power research in fusion technologies, nuclear deterrence, and radiation testing.

LEVERAGING NEW TALENT > Interns Allison Komrska and Ronald Gomillion designed and analyzed simulations.



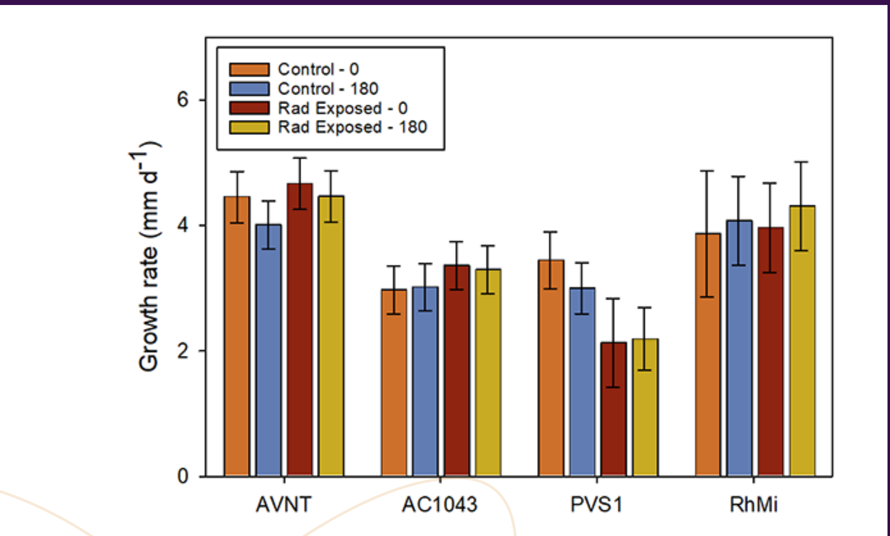
Electron flows (moving to the right) in high power transmission lines are boosted significantly by ions (moving top to bottom).

Decoding behaviors of filamentous fungi in high radiation environments

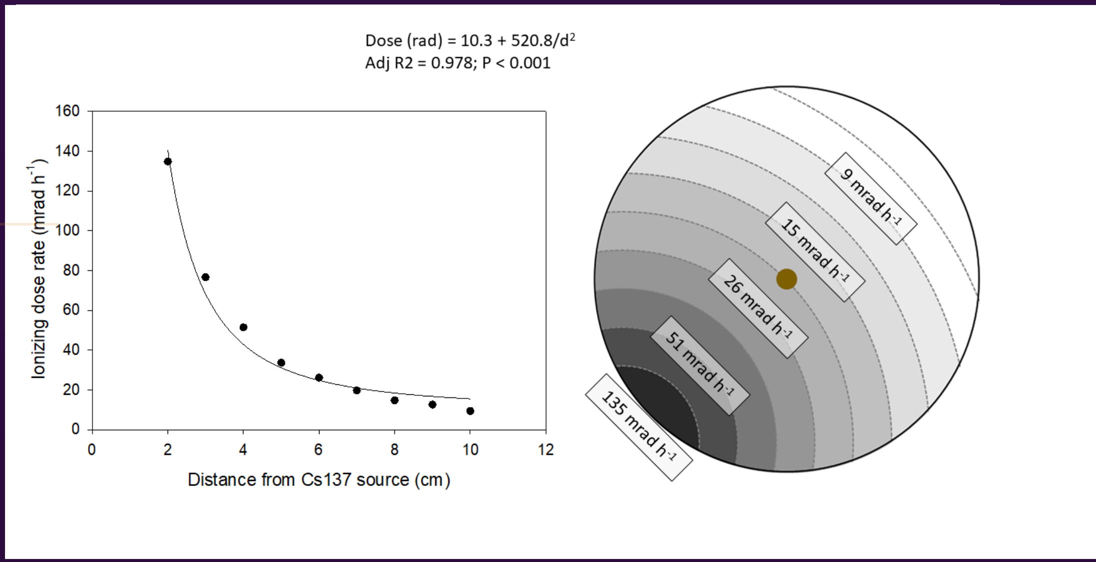
Sandia researchers are exploring the intriguing behavior of certain darkly pigmented fungi that thrive in high radiation environments. These fungi exhibit a trait known as radiotropism, which is the growth toward sources of ionizing radiation. However, inconsistencies in experimental methods have made it difficult for the team to fully understand the factors that regulate this behavior.

In a recent study, Sandia researchers assessed radiotropism in four fungal isolates by placing cultures near a cesium-137 source and measuring the growth of mycelia over seven days. Surprisingly, the team found no significant differences in growth rate or direction, indicating a lack of measurable radiotropism in these experiments.

To deepen understanding, Sandia researchers plan to conduct additional studies that will vary gamma emission rates and energies. The team will also explore other types of ionizing radiation, such as alpha and beta particles and neutrons. These efforts aim to uncover the critical factors that drive radiotropic behavior in filamentous fungi, potentially leading to new insights in radiation biology and applications in extreme environments. (PI: George Bachand)



Growth rate data show that the four fungi do not exhibit radiotropic behavior toward the cesium-137 source.



Graphical representation of the ionizing radiation gradient experienced by the fungi as they grow outward from the central brown plug.

Developing a rapid, multiplexed viral pathogen detection platform

Sandia researchers utilized a metal-organic framework to develop a rapid, sequence-based, multiplexed platform for viral pathogen detection. Their platform facilitates quick, easy redesign to address emerging pathogens and has significant implications for pandemic response by enabling timely, effective detection of viral threats.

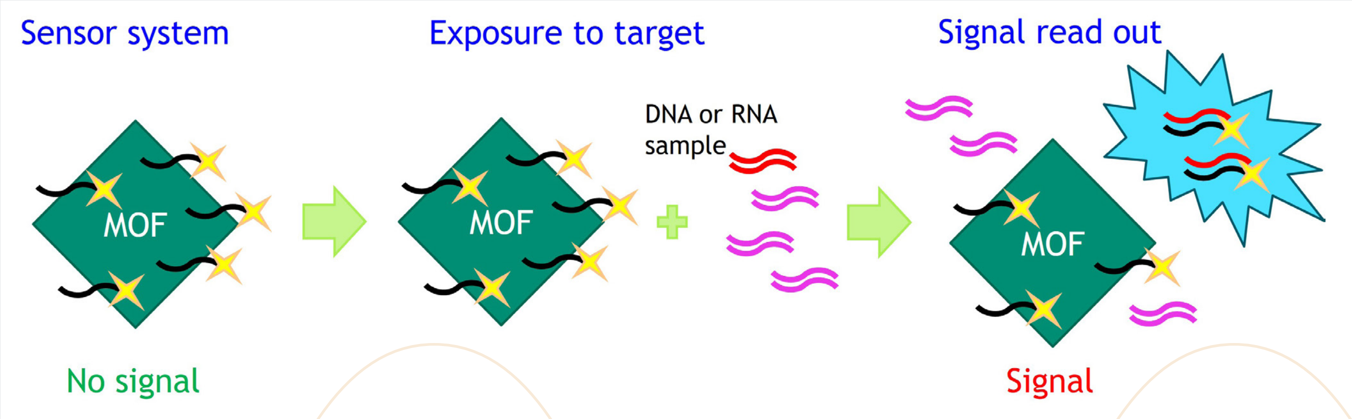
Researchers collaborated with Sandia Alliance partner University of New Mexico and Florida A&M, A&M, a Sandia Securing Top Academic Research & Talent at HBCUs partner, and benefited from postdoc and intern contributions. The research team presented their work at conferences, including the Chemical & Biological Defense Program Defense Threat Reduction Agency & Gordon Conferences, fostering dialogue and collaboration.

Building on the knowledge derived from this LDRD, the team is currently engaged in follow-on projects, particularly in their role as Test and Evaluation for Intelligence Advanced Research Projects Activity. (PI: Kimberly Butler)

READ MORE > *ACS Nano*, *Journal of the American Chemical Society*

COOL FACT > The developed platform has national defense applications in combating pandemics and enhancing viral detection capabilities.

LEVERAGING NEW TALENT > Key contributors include postdocs Eric Sikma, Jacob Deneff, and David Fairchild, and student interns Elizabeth Nail, Elizabeth Zapien, Trini Tran, Emily Bai, and Patrick Williams (recruited through START HBCU partner Florida A&M). Kauryn Datcher, who has worked on the project for more than a year, was recruited from HBCU Talladega College, and is now working remotely supporting the project while completing her PhD in chemistry at Vanderbilt.



Development of a novel metal-organic framework-based sensor system capable of rapid detection of viral DNA or RNA without the need for complex equipment.

Leveraging microbial innovations to address methane emission challenges

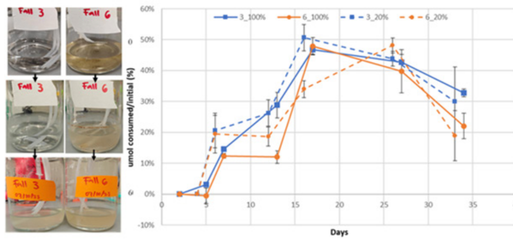
Gas leaks, livestock and landfills all contribute to dilute and distributed methane emissions. To help minimize these, a Sandia LDRD team worked to generate stable methane-consuming microbial consortia for deployment in engineered environmental systems. By producing stable inocula of these consortia and implementing viral controls for microbes that generate methane, emissions can be significantly reduced.

Collaboration with Sandia Securing Top Academic Research & Talent a HBCUs partner Prairie View A&M was essential for understanding the biochemical steps that limit biological methane production and consumption.

Sandia researchers presented at conferences such as Goldschmidt 2024 and the SIMB Industrial Microbial Communities. This work has potential applications in bioenergy and geosciences. (PI: Ryan Wesley Davis)

READ MORE > *Algal Research*, *Scientific Reports*

LEVERAGING NEW TALENT > Postdoc Jihoon Yang analyzed environmental microbial communities, and postdoc Ben Diaz identified viral hosts for the microbes in the samples. Student interns Jessica Weise and Kasim Mohammed also played important roles.

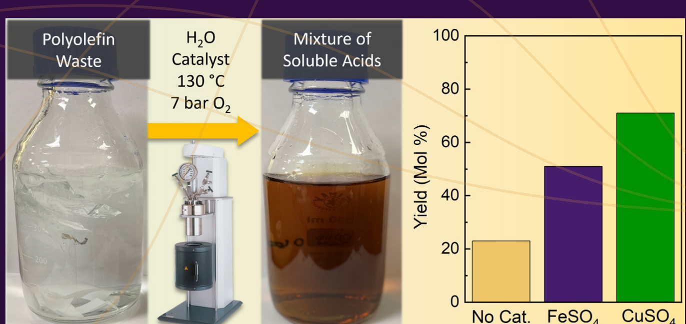


Long-term studies show distinct microbial consortia utilize 50% methane in native and reconstituted conditions relative to controls.

Converting plastic waste into valuable resources for a greener future

Sandia researchers, in collaboration with Sandia Alliance partner Georgia Tech and Professor Zhaohui Tong, are developing a chemical conversion strategy to deconstruct polyethylene, a common plastic, into valuable products for bioconversion.

The findings were presented at major conferences, including the American Chemical Society National Meeting, Plastics Recycling and Upcycling: Gordon Research Conference, and the Society for Industrial Microbiology and Biotechnology.



Sandia has secured funding from DOE to further these efforts, with leadership by Hermant Choudhary. (LDRD PIs: Oleg Davydovich, Michael Kent)

READ MORE > *Green Chemistry*, *Polymer Degradation and Stability* (*1*) (*2*), *Journal of Industrial Microbiology and Biotechnology*, and *RSC Sustainability Polymer Chemistry*

COOL FACT > This chemical conversion approach aims to create a low-cost, sustainable method for upcycling plastics into useful chemicals, fuels, and feedstocks.

LEVERAGING NEW TALENT > Postdocs Oleg Davydovich, Amit Jha, and Nathan R. Bays and intern Jay Salinas were integral to this project.

A mild aqueous method transforms polyethylene into valuable water-soluble acids using cost-effective copper and iron salts.

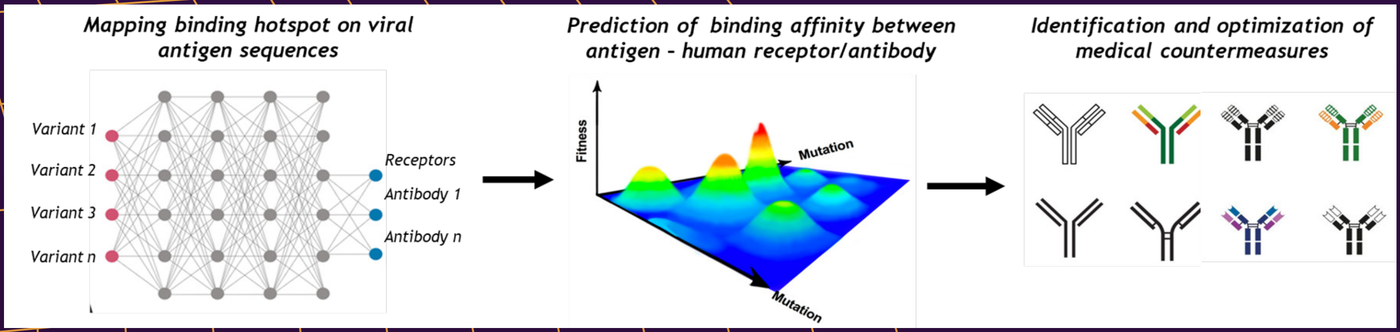
Enhancing medical countermeasures with innovative machine learning models

At Sandia, an LDRD team has developed an innovative approach that combines domain-informed data mining, experimental biology, and machine learning to predict the binding efficacy between the human receptor/antibody and potential variants of the SARS-CoV-2 receptor binding domain. The model identified several potent heavy chain-only antibodies with high binding and neutralizing efficacy against existing SARS-CoV-2 variants, including Omicron BA.1 and BA.5, without requiring further experimental screening.

Sandia researchers have submitted U.S. patents and presented at conferences such as the Chemical and Biological Defense Science & Technology 2023 and 2024.

The team leveraged this to secure Defense Threat Reduction Agency (DTRA) funding for continued development with other virus strains in the same family and has potential applications in medical countermeasures development and biosurveillance, with follow-on projects from DTRA and the Department of Homeland Security. (PI: Le Thanh Mai Pham)

LEVERAGING NEW TALENT > Postdoc Thomas Sheffield contributed as a specialist in machine learning modeling, and postdoc Ryan Bruneau conducted essential virology experimental work.

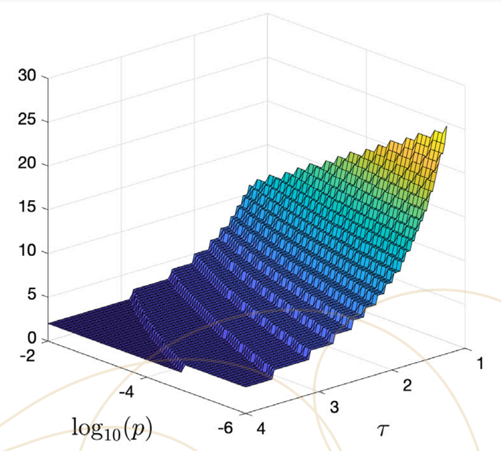


Machine-learning guided identification of potential medical countermeasures against potential variants.

Breaking logjams in adoption of scalable algorithms for matrix computations

Numerical linear algebra (NLA) is of incredible importance to computational science. Despite this, prevailing NLA libraries have little to no support for scalable randomized algorithms developed over the past twenty years. In this LDRD, Sandia made major strides in bringing these randomized algorithms to mainstream NLA.

One of the team's key achievements was the release of RandBLAS: a trustworthy C++ library for linear dimension reduction. Building on this, the team developed code for a notoriously challenging matrix decomposition known as "QR with column pivoting." For the first time ever, this decomposition can be computed equally well on many-core processors and artificial intelligence accelerators, which has created new possibilities for data processing and experiment design.

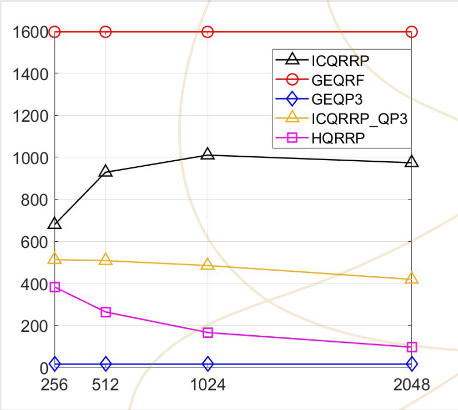


Visualization of minimum dimensions needed in one of RandBLAS' statistical tests, running under different parameter settings.

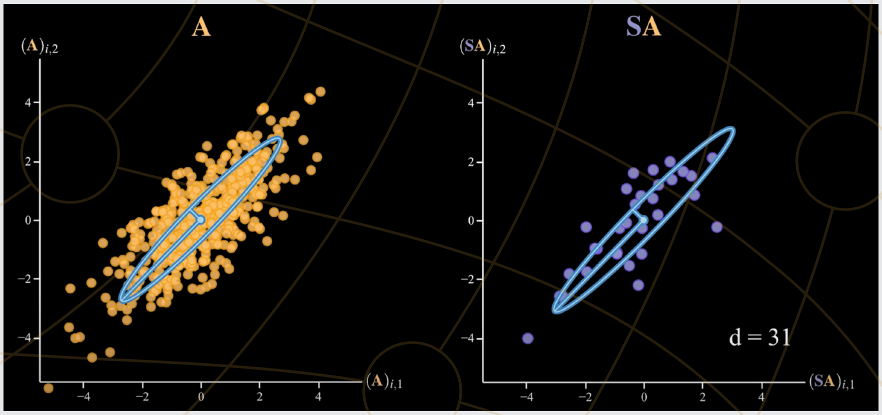
This work leveraged collaborations with Sandia Alliance partner UC Berkeley, UT Knoxville, and researchers in industry. It has been disseminated through four conference presentations and an invited seminar at Rice University. Collaborator follow-on projects to enhance RandBLAS are already under way. (PI: Riley John Murray)

READ MORE > *arXiv*

LEARN MORE > *Is the Future of Linear Algebra...Random?* (An educational YouTube video on randomized NLA with over 380,000 views)



New pivoted QR algorithm (black) is 100x faster than the classical method (blue) and nearly achieves the theoretical limit (red).



Sketching a large dataset produces a smaller, yet similar dataset.

Elevating trustworthiness of machine learning systems through data geometry

Sandia researchers are researching ways to quantify the trustworthiness of machine learning (ML) predictions through geometric representations of the data. While previous efforts primarily focus on model outputs and calibration techniques, this LDRD team innovatively compares geometric properties of training data with those from inference data.

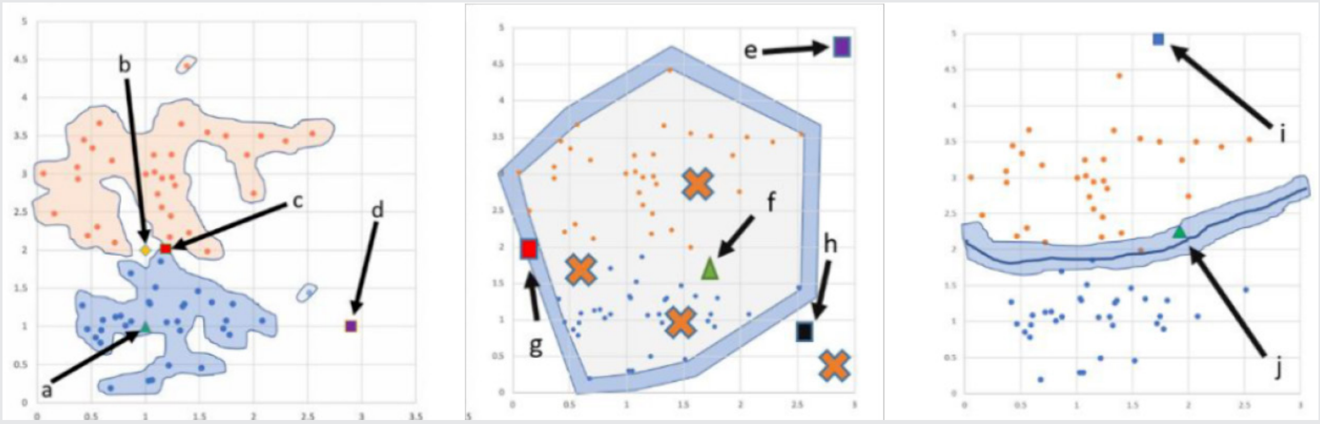
The benefits of this research are significant and have broad applications across mission spaces that utilize ML. First, the output of ML models can be more trustworthy, enhancing their reliability. Second, the training data can be scrutinized for anomalies or under representation, leading to better data quality. Finally, this work fosters a deeper understanding of the ML model.

The U.S. National Defense Strategy and the Advanced Simulation and Computing programs have leveraged this work for out-of-distribution detection and trust scores, and the team is engaged with the test and evaluation and red teaming of ML systems.

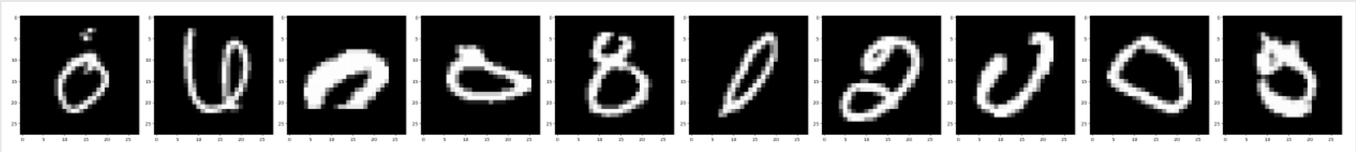
The team has shared these findings through presentations at the U.S. National Congress on Computational Mechanics and various customer conferences. (PI: Mike Reed Smith)

READ MORE > *Mathematics Journal*

LEVERAGING NEW TALENT > Graduate student Ellery Wuest from Sandia National/Regional partner New Mexico State University contributed to this project, and postdoc Esha Data explored topological data analysis.



Visualizing geometric uncertainty: Are test points represented by training data? Are test points near ambiguous regions? Are test points extrapolated?



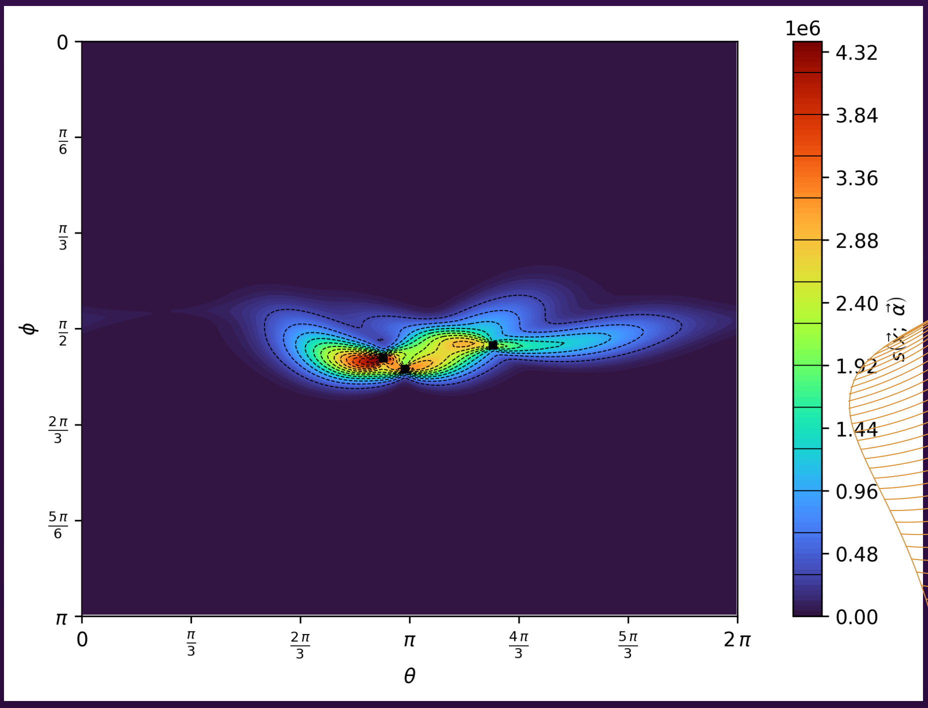
The ten least trustworthy test data points classified as the zero class, flagged for additional scrutiny by Sandia's method.

Enhancing interpretability of scattered data approximation for machine learning applications

Sandia researchers have created a method for approximating complex data on manifolds (mathematical structures used for modeling). By combining linear regression techniques for global features with radial basis function networks for local features, the team has developed efficient and interpretable approximations. These advancements are crucial for training machine learning algorithms, including deep operating neural networks, which can be utilized across numerous mission spaces.

Sandia researchers recently presented their findings at the 2024 Society for Industrial and Applied Mathematics Annual Meeting and are preparing a manuscript for submission to the *Journal on Computational Physics*.

Follow-on research is underway within the DOE Early Career Research Award project led by Pete Bosler.
(PI: Jason L. Torchinsky)



Approximation of column-integrated sulfate in the atmosphere generated by the 1991 Mount Pinatubo Eruption.

Accelerating mission-informed co-design with RISC-V ecosystem advancements

Sandia researchers aimed to enhance the speed, fidelity, and quality of mission-informed hardware and software co-design using the open, non-proprietary Reduced Instruction Set Computing-V (RISC-V) ecosystem, which allows a community of developers and researchers to contribute to the architecture design. This project developed the RISC-V high-performance computing software stack, integrated RISC-V into Sandia's co-design infrastructure, enabled FPGA-accelerated simulation, and built partnerships with universities and vendors. Sandia demonstrated RISC-V's capability to support co-design with full operating systems and complex DOE applications, paving the way for future R&D efforts.

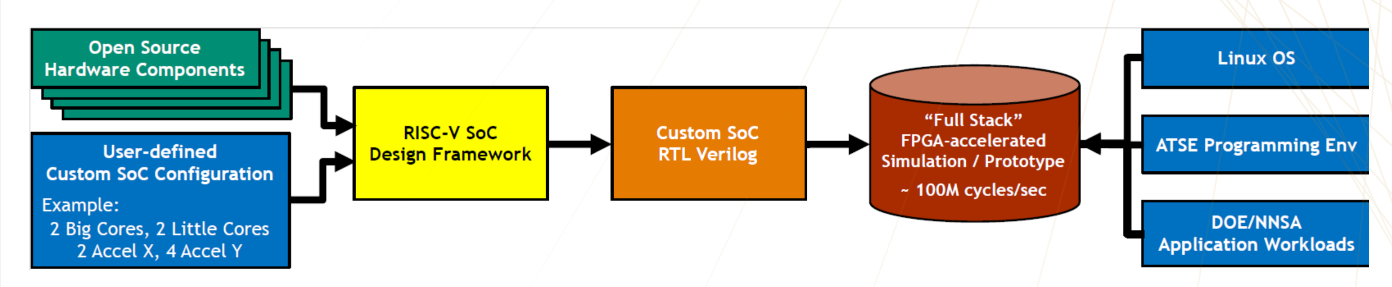
Collaboration with Sandia Alliance partner Purdue and Professor Tim Rogers was crucial, supporting the creation and evaluation of RISC-V cores integrated with a single instruction-multiple threads (SIMT) compute unit. This partnership provided valuable data and produced custom ASICs.

Sandia researchers published papers and presented at conferences, sharing advancements in RISC-V technology. This work has potential applications in nuclear deterrence and global security and sets the stage for future RISC-V projects. (PI: Kevin Pedretti)

Kevin Pedretti is a distinguished researcher in the Scalable System Software department at Sandia. He led the RISC-V ecosystem advancements LDRD project team.

READ MORE > Lecture Notes in Computer Science

LEVERAGING NEW TALENT >
The project supported three Sandia summer interns, Nicholas Gordon, Griffin Dube, and Liam Cooper, who contributed to various RISC-V support and integration tasks.



Full-stack co-design framework.

Using hardware emulation to uncover design vulnerabilities in digital circuits in the presence of faults

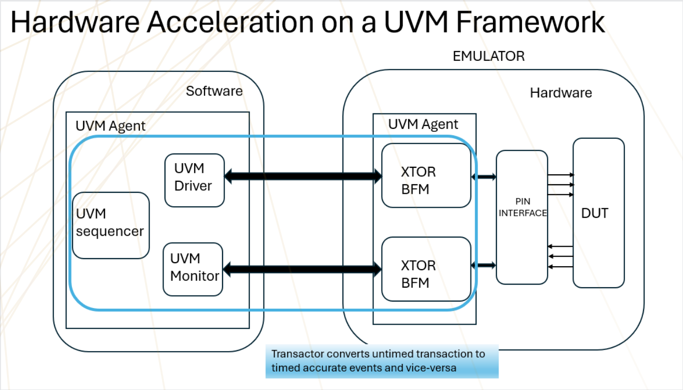
At Sandia, the Digital Adversarial Test and Exploration Lab is addressing the challenge of assessing the reliability and robustness of digital circuits during design. Traditional methods, which involve inserting faults into digital models, can be computationally intensive and time-consuming. To improve this, researchers are using hardware emulation to accelerate fault assessments by mapping digital designs onto reconfigurable hardware, allowing precise control over the types and locations of faults injected.

This innovative approach significantly shortens the verification and validation process compared to traditional simulation methods. The emulator can replicate various fault types, including radiation-induced faults, stuck-at faults, transient faults, and bridge faults.

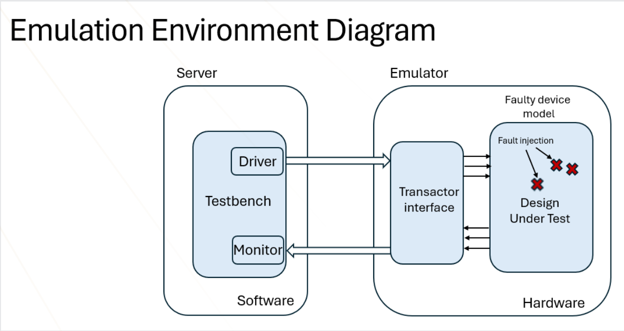
Insights from this research can enhance fault tolerance, reliability studies, radiation-induced fault analysis, and hardware security. Looking ahead, Sandia plans to pursue additional projects to explore the benefits of hardware emulation and develop essential tools for hardware assurance and security, underscoring its commitment to advancing digital circuit design. (PI: Yalin Hu)

PI Yalin Hu is employing hardware emulation to greatly reduce the time required for verification and validation when evaluating the reliability and robustness of digital circuits during the design phase.

LEVERAGING NEW TALENT > Sandia MissionTech intern Elmir Dzaka contributed to this project and then transitioned to a year-round internship. He was also selected to be in the Sandia's 75th Anniversary Student Showcase. Postdoc Luis Bustamante contributed to the Veloce Fault App related development of the project.



Hardware acceleration utilizing a Universal Verification Methodology (UVM) framework.

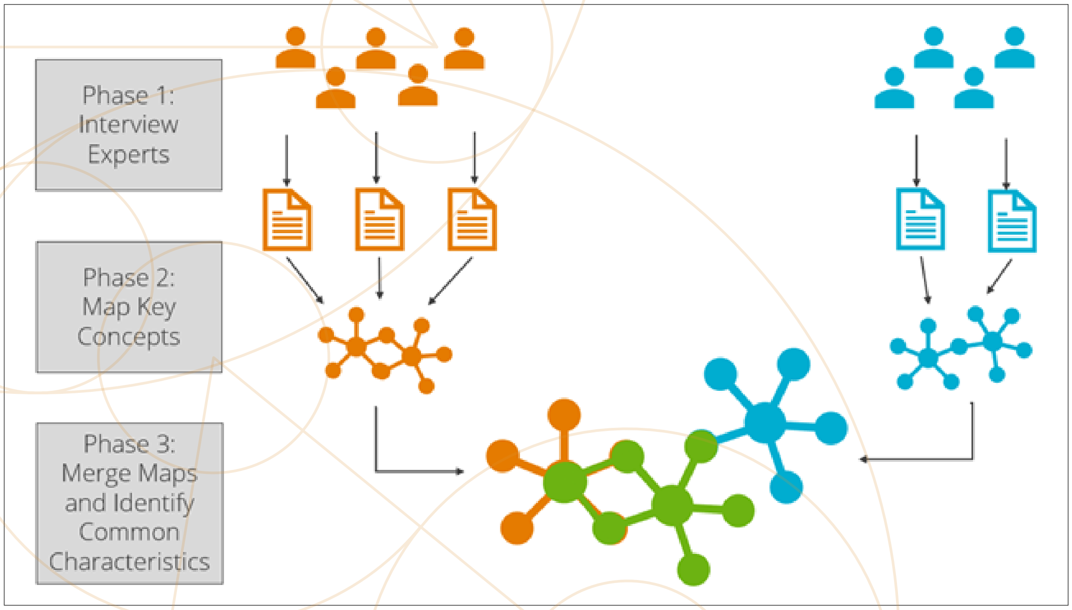


An emulation environment that can be used to uncover design vulnerabilities in digital circuits in the presence of faults.

Developing a common language for effective system risk analysis of critical national security systems

Holistic systems-level risk assessment is essential for assuring digital systems, especially those that are critical to national security. Assessing these systems often requires evaluating various components using different analysis techniques. Currently, combining results from these techniques into a comprehensive system risk statement is a slow and manual process. Sandia researchers identified two key challenges: 1) communication gaps between research communities and 2) specialized outputs from different analysis techniques.

Over five months, the team conducted thirteen interviews with practitioners in risk assessment and software analysis at Sandia. These discussions revealed common themes, terminology, and challenges faced across several Sandia communities. Important ideas and connections were structured as concept maps. The team has secured funding for the next two years to build on these insights, engage more communities, and develop a shared framework that will help define, plan, execute, and analyze the overall results of a multi-technique system risk analysis. (PI: Jamie Elisabeth Thorpe)



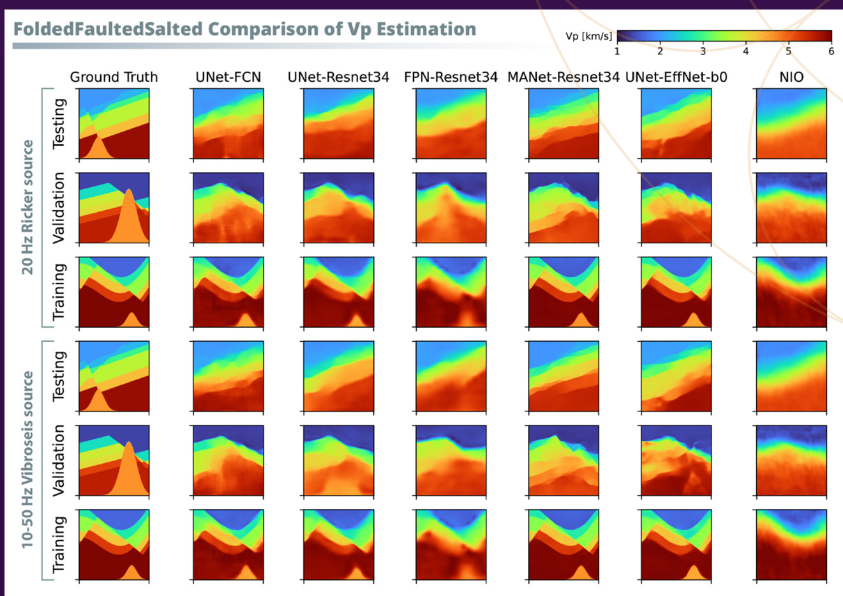
A three-phase approach to characteristic discovery.

Accelerating seismic analysis to enhance global security and energy solutions

Analyzing and modeling seismic data has traditionally been computationally expensive and labor-intensive. By utilizing deep learning techniques, a Sandia LDRD team aims to accelerate seismic full waveform inversion for subsurface characterization.

The benefits of this research include faster estimation of seismic velocity directly from full seismic waveforms, which is essential for characterizing geologic layers and faults in the subsurface. Sandia researchers have also identified future methodology needs for practical applications.

Sandia researchers have shared their findings through presentations at the Seismological Society of America, the IMAGE conference, and the annual ACES Community of Practice poster symposium. This innovative work has the potential to impact mission spaces such as Global Security and Energy and Homeland Security, paving the way for more efficient seismic analysis. (PI: Jenny Logan Harding)



LEVERAGING NEW TALENT >
Collaboration has been crucial to this project, with key contributions from Scott Gauvain, a Sandia intern who transitioned to staff, and Abdo Elmeliegy, a postdoctoral researcher working with Professor Mrinal Sen from Sandia Alliance partner University of Texas at Austin.

Seismic velocity estimations for six deep learning models, shown for different testing, validation, and training samples and two seismic sources.

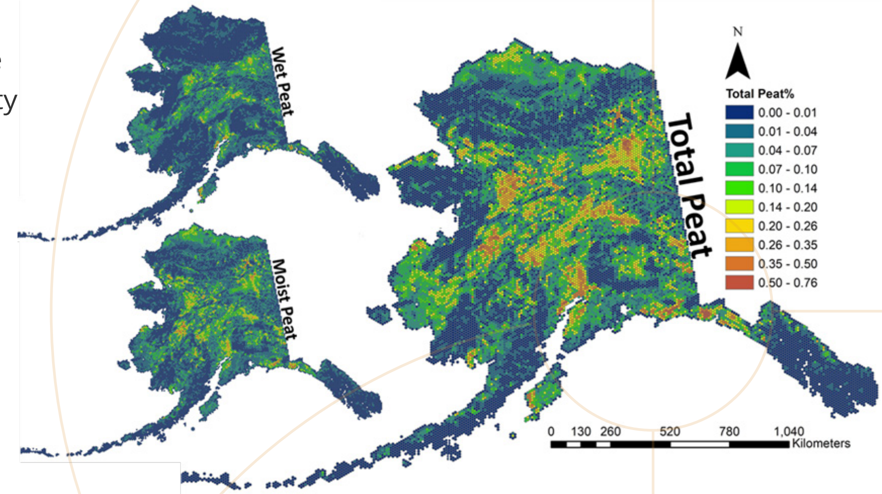
Quantifying carbon emissions to enhance disaster preparedness

Sandia researchers are increasing understanding of carbon loss from Alaskan peat fires. This research quantifies carbon emissions, providing data for Earth system models. Collaborations with the U.S. Forest Service, Alliance partner University of Illinois Urbana-Champaign (Illinois), the University of Edinburgh, and the National Institute of Standards and Technology (NIST) have been essential to the project.

Outside of Sandia, key contributors include Mark Lara, (Illinois); Rory Hadden (University of Edinburgh); Sara McAllister (U.S. Forest Service); Isaac Leventon (NIST).

Finding have been published in *Scientific Data – Nature Research* (accepted with revisions) and four papers are under review. The team has presented their work at numerous conferences, including the American Geophysical Union Annual Meeting and the International Association of Wildland Fire. This research has significant implications for disaster preparedness, and Sandia is seeking funding for follow-on projects to continue this important work. (PI: Sarah Scott)

LEVERAGING NEW TALENT > Raquel Hakes Weston-Dawkes and Sagar Gautam were Sandia postdoc researchers on this project who transitioned to staff.



High-resolution maps of Alaska show peatland extent, using color-coded hexagons to indicate varying peat percentages.

Creating frameworks and diverse scenarios for stratospheric aerosol injection decision support

Needed: An assessment framework for Stratospheric Aerosol Injection (SAI), along with diverse scenarios that reflect the technology and infrastructure limitations of SAI deployment that could be used to develop scenarios for effective decision support.

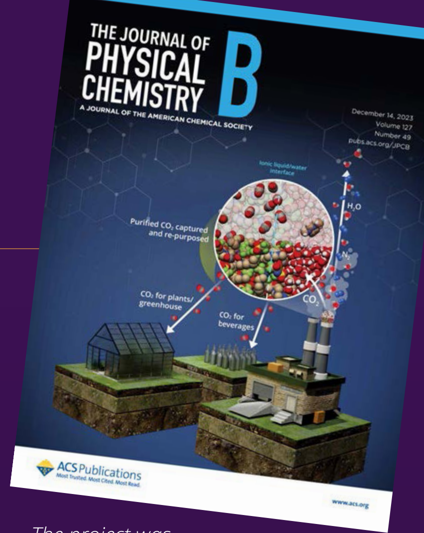
Sandia's researchers responded to the need. They adapted performance assessment methodology from nuclear waste disposal to create an evaluation framework for SAI scenarios. They also developed a novel method for SAI scenario design and simulation using the DOE's Earth System Model, enhancing understanding of SAI timing.

This work aligns with the needs in the Office of Science and Technology Policy's 2023 Solar Radiation Modification Report, contributing to the number of models conducting SAI simulations and increasing the diversity of SAI scenarios. Sandia presented on this topic at the Geoengineering Model Intercomparison Project Annual Workshop and is pursuing follow-on research to understand impacts of SAI scenarios with infrastructure constraints on regional tipping elements. (PI: Lauren Wheeler)

READ MORE > *Frontiers in Environmental Science*

LEVERAGING NEW TALENT > Jessica Lien joined Sandia as a graduate student intern and transitioned to staff.

Creating synergistic membranes for effective CO2 capture and electrochemical conversion



The project was featured on the cover of Journal of Physical Chemistry B.

Sandia researchers are exploring innovative ways to capture carbon dioxide (CO2) and electrochemically convert it into useful products. The team has developed a cutting-edge nanoporous membrane designed for efficient capture and conversion, potentially lowering capture costs while producing carbon-neutral chemical feedstocks. The advanced membrane features three functional layers: a capture layer, a transport layer, and an electrocatalytic conversion layer, all of which must work together effectively. Through collaboration with Oregon State University, molecular modeling was conducted to understand CO2 behavior within the membrane layers, crucial for successful fabrication. The team also performed electrochemical CO2 reduction studies to assess the effects of the layers and the overall membrane functionality. New testing methods were created to analyze reaction products. The results show these novel membranes efficiently combined CO2 capture and electrochemical conversion in a single functional architecture.

PI Stephen Percival is a materials scientist who recently led an LDRD team exploring innovative ways to capture carbon dioxide and convert it into useful products.

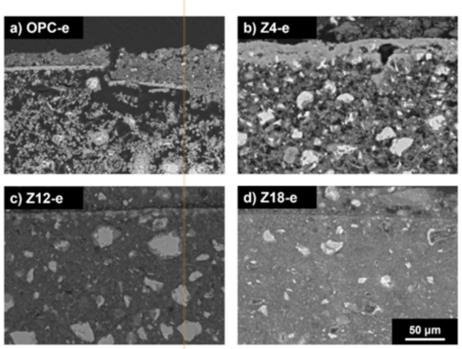
The project's accomplishments include publications, 10 presentations, including ones at ACS and ECS conferences, and three patents (one non-provisional filed and two non-provisional to be filed). (PI: Stephen Percival).

READ MORE > *The Journal of Physical Chemistry B, Langmuir*

LEVERAGING NEW TALENT > The LDRD team comprised two postdoctoral researchers, including Danielle Richards and Calen Leverant, and two summer interns, Zephan Bornreund and Juan Rojas.

Enhancing concrete sustainability and reducing the carbon footprint through pozzolanic materials

A significant carbon footprint is associated with construction and building materials such as cement and concrete. By incorporating natural pozzolanic materials like zeolites, a Sandia research team, who collaborated with Professor Jeffrey Bullard from Sandia Alliance partner Texas A&M, is enhancing the microstructure of cement to promote increased carbonation over the life of the material while decreasing the amount of cement in the concrete.



Scanning electron microscopy images of the carbonated top-layer of cement-zeolite samples with varying zeolite concentration (Z4, Z8, Z12) after 28 days.

The results have implications for industrial processes with follow-on projects funded by DOE. (PI: Jessica Rimsza)

READ MORE > *Construction and Building Materials*, *Cement and Concrete Composites*

COOL FACT > The combination of these innovative approaches leads to passive carbon uptake, offsetting the material's carbon emissions.

LEVERAGING NEW TALENT > Postdoc Atolo Tuinukuafe, early career staff members Chven Mitchell and Melissa Mills, and undergraduate intern Angus Moore (Purdue University) contributed to this LDRD.

Transforming silicones to enhance design flexibility in engineering applications

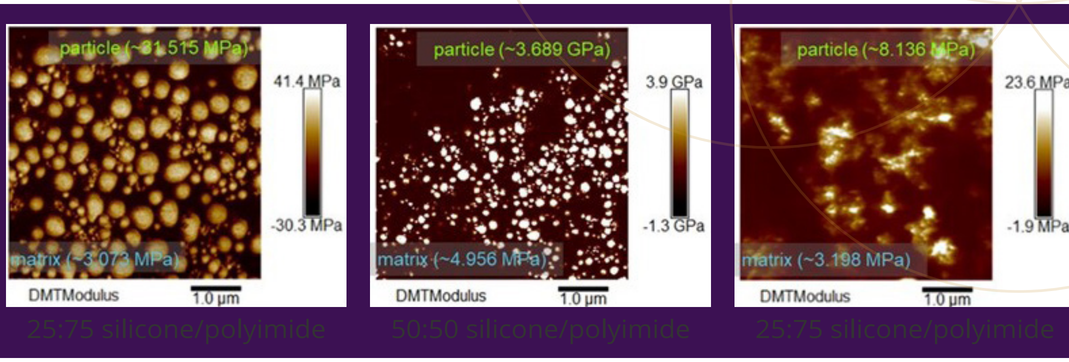
Silicones are essential in many technologies as they possess unique properties, but they also have high coefficients of thermal expansion (CTE), which leads to dimensional changes that can complicate engineering applications. A Sandia LDRD team is developing silicone/polyimide interpenetrating polymer networks to create silicones with lower CTE. Their innovative approach combines the thermal stability of polyimides with the elastomeric properties of silicones, aiming to reduce dimensional changes by at least 33%.

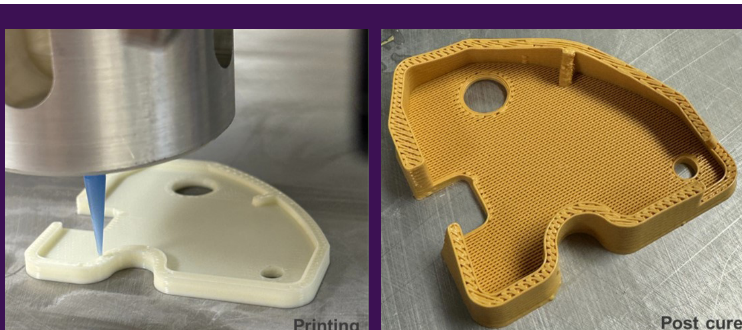
This research will provide engineers greater design flexibility through lower CTE silicones and also enhance the fundamental understanding of interpenetrating polymer network formation.

The team secured FY25 funding and will submit full LDRD proposals for further research. This work has the potential to impact mission spaces including national defense, energy, and advanced materials. (PI: Leah Appelhans)

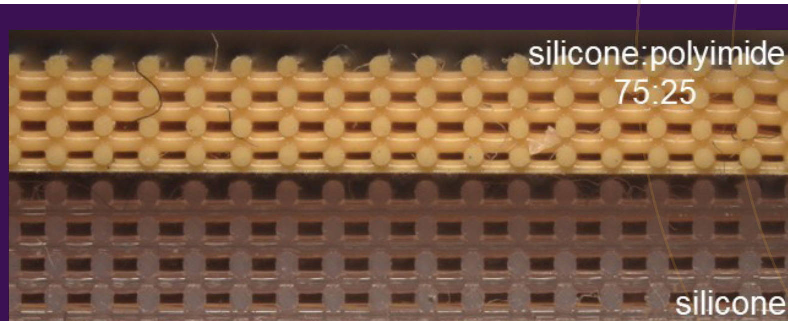
COOL FACT > The team created formulations compatible with direct-ink-write additive manufacturing, a crucial technique for producing silicone components at Sandia.

Atomic force microscopy scans showing differences in modulus and phase separation for different silicone/polyimide formulations.





3D printed UUR silicone/polyimide compression pad shown during printing (left) and after the curing process (right).



Cross sections of 3D printed silicone/polyimide lattices, compared to silicone alone, showing excellent maintenance of form factor and lattice geometry.

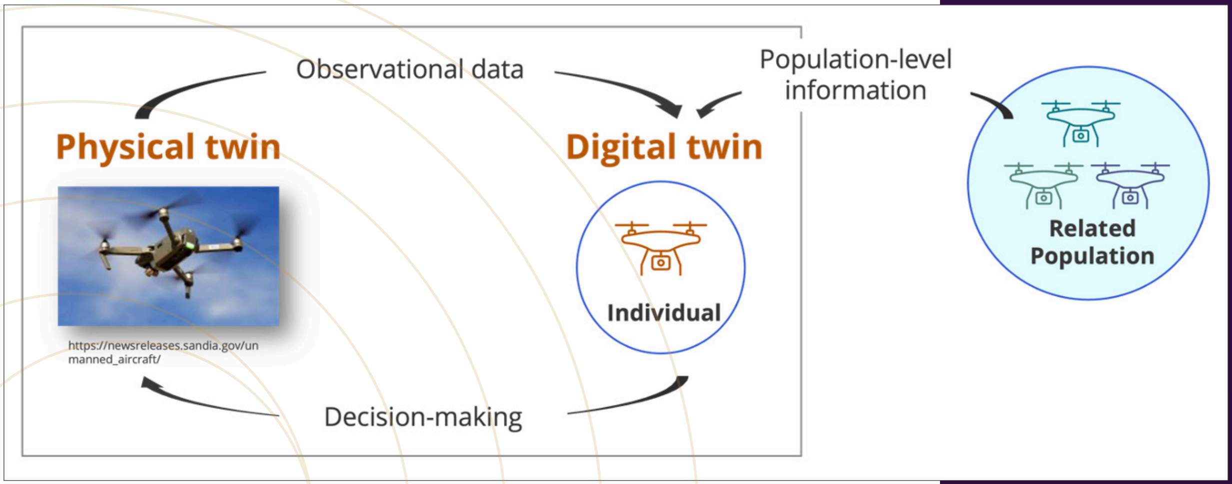
Improving digital twin reliability by leveraging data from related assets

Digital twins predict the health and evolution of physical assets over time. By developing innovative techniques to leverage data from related assets, Sandia researchers are addressing a key challenge—acquiring sufficient data to inform the underlying computational models and ensure trustworthy decision-making.

In collaboration with Professor Troy Butler at University of Colorado Denver, Sandia researchers demonstrated that this approach constrains prior assumptions and reduces uncertainty in subsequent Bayesian inferences for an individual asset, which could significantly reduce the amount of experimental data needed for reliable digital twins. Their findings were shared through a paper submitted to the *SIAM Journal of Uncertainty Quantification*, invited lectures at Emory, Brigham Young, and Sorbonne University, and presentations at several prestigious conferences.

The developed capabilities provide an enabling technology for Sandia's digital engineering initiatives and could be a vital tool for agile and responsive national defense solutions. Follow-on work will leverage this framework to guide the acquisition of experimental data. (PI: Rebekah Dale White)

Rebekah White and her LDRD team developed capabilities that provide an enabling technology for Sandia's digital engineering initiatives and could be a vital tool for agile and responsive national defense solutions.



Leveraging population-level information can improve the reliability of digital twins for decision-making.

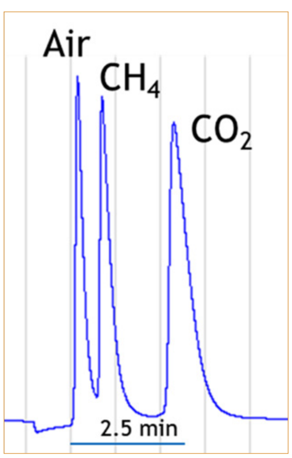
Creating miniature, low-power, universal atmospheric gas sensors

Developing inexpensive, low-power, universal atmospheric gas monitoring devices is a critical need. By creating accurate and affordable sensors, Sandia aims to make atmospheric gas measurements more widespread and enable portable breath research instrumentation. The measurement system relies on miniaturized chemical sensing hardware, including gas chromatography devices, developed through years of innovative silicon micromachining at Sandia.

Sandia published findings in the IEEE Sensor conference proceedings and submitted two patent applications: one for a novel gas chromatography column fabrication method and another for a catalytic detector for gaseous oxidized carbon.

This work has potential applications relevant across multiple mission spaces. The team is actively seeking follow-on funding through the DOE Technology Commercialization Fund and other research grant opportunities.
(PI: Phillip Miller)

LEVERAGING NEW TALENT > Postdoc Ashur Rael's work was vital to the project's success.



Data demonstrating separation and measurement of atmospheric gases.

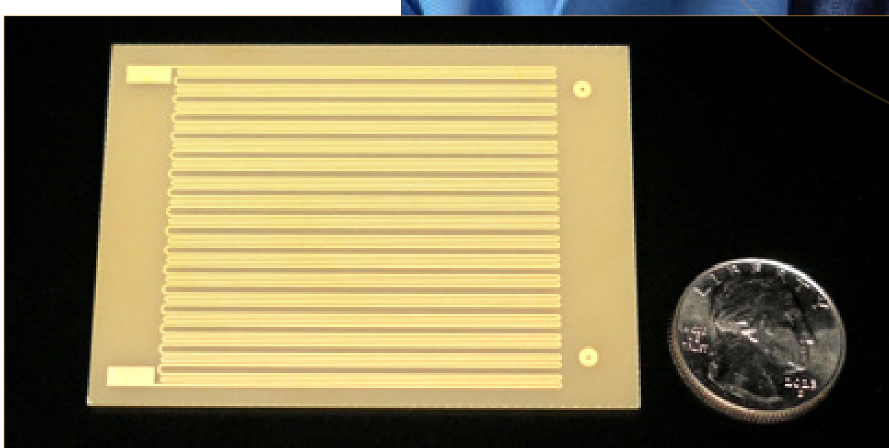
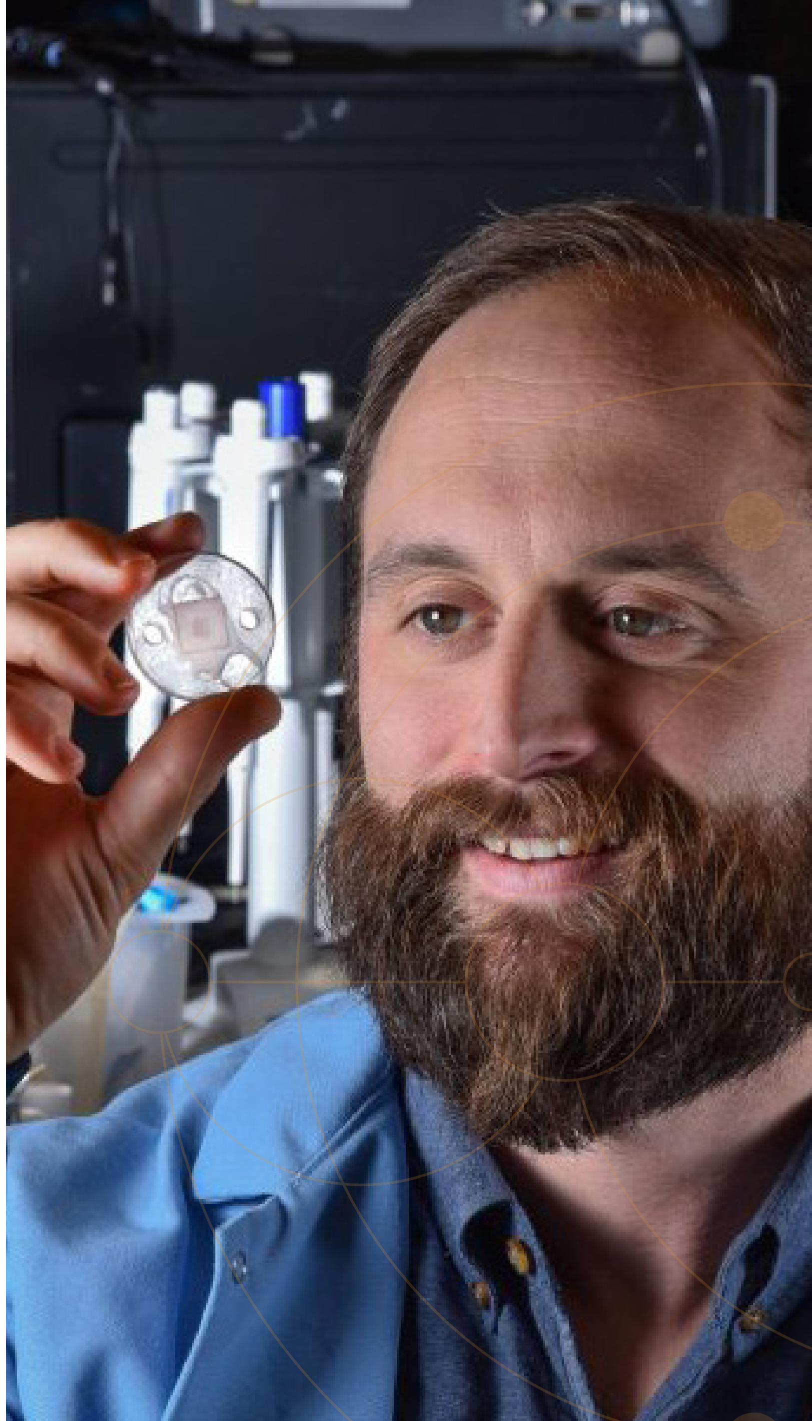


Image of gas chromatography device in relation to US quarter for separation of atmospheric gases.



Sandia researcher Philip Miller led the LDRD team working to create miniature, low-power, universal atmospheric gas sensors.

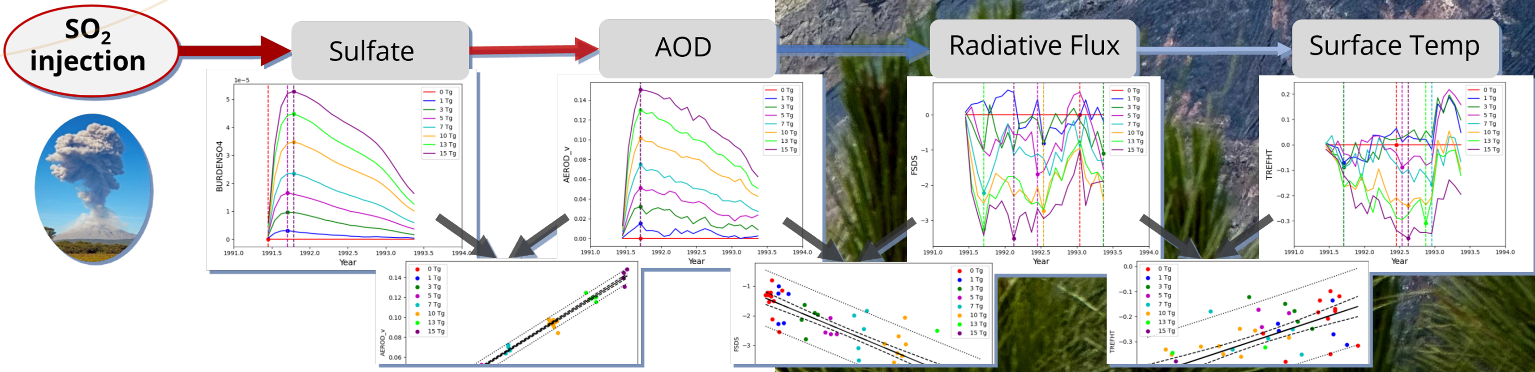
CLDERA LDRD Grand Challenge

Societally and security-relevant impacts from short-term and localized sources of sulfur dioxide (SO2) are the product of multiple complex interacting processes that can arise over small regions and timeframes making reliable attribution difficult.

Through this project, Sandia researchers have enabled multi-step attribution of downstream impacts and developed methods to (1) distinguish how a localized source drives the planet's climate system to respond and (2) to trace the pathway of physical processes that connect a source through space-time back to an impact. The methods have been demonstrated on simulations and observations of the 1991 eruption of Mt. Pinatubo in the Philippines. (PI: Diana Bull)

COOL FACTS > The CLDERA project has generated 1750 simulated years of ensembles from a CLDERA-enhanced energy Exascale Earth System Model V2 stratospheric prognostic aerosol, and nine pathway and attribution method code releases.

LEVERAGING NEW TALENT > Contributing to this LDRD were postdocs Graham Harper (now converted to staff), Chris Wentland, Kellie Lynn Mcclernon, Meredith Guenevere Longshore Brown, Max Carlson, Hunter Brown, Drew Yarger, and Michael Weylandt. Interns Joe Hollowed, Allen Hu, Sam Shi-Jun, Jake Nichol, and Rob Garrett also participated in this project.



Example of modeled relationships between a volcanic eruption and downstream change in surface temperature employed in multi-step attribution.

Douglas Medlin, a distinguished scientist at Sandia and LDRD PI, led a collaborative team in researching how crystal defects control grain boundary behavior.

Discovering how crystal defects control grain boundary behaviors

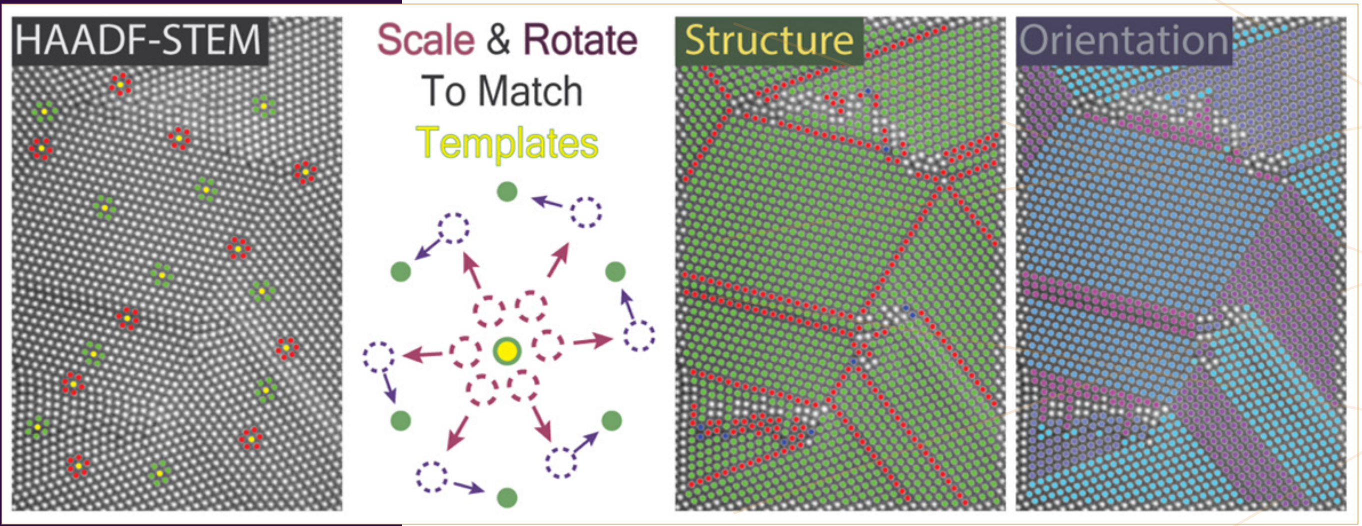
The interfaces between differently oriented crystals, known as grain boundaries, control the properties of all polycrystalline materials. However, the atomic-scale mechanisms for these effects have been elusive. Researchers, in collaboration with University of Florida (a Sandia National/Regional partner) and Université de Lorraine, made fundamental discoveries into how crystalline defects affect the atomic and nanoscale behavior of grain boundaries.

The team combined controlled growth of nanocrystalline thin films, atomic resolution microscopy, and molecular dynamics and micromechanics modelling to determine the interplay between atomic structure and compositional segregation at crystalline defects within grain boundaries.

The team's methodological advances for analysis of atomic resolution microscopy data were released as an open-source code, 2D-PTM. (PI: Douglas Medlin)

READ MORE > *Acta Materialia* (*1*), (*2*), (*3*), *J Physical Chemistry Letters*, *Physical Review Materials*, *Computational Materials Science*, *Materials Characterization*

LEVERAGING NEW TALENT > The project benefited from the contributions of six postdoc appointees, Chongze Hu, Daniel Vizoso, Alejandro Hinojos, Kyle Dorman, James Nathaniel, and Matias Kalaswad. (Nathaniel and Kalaswad both converted to staff at Sandia.) PhD student Miguel Fernandez and undergraduate student interns Nico Fuchs-Lynch and Darcey Britton were also involved with this successful project.



The 2D-PTM code enables high-throughput analysis of atomic resolution microscopic images of nanocrystalline grains.

Harnessing porous materials for safer and more effective rare earth element separations

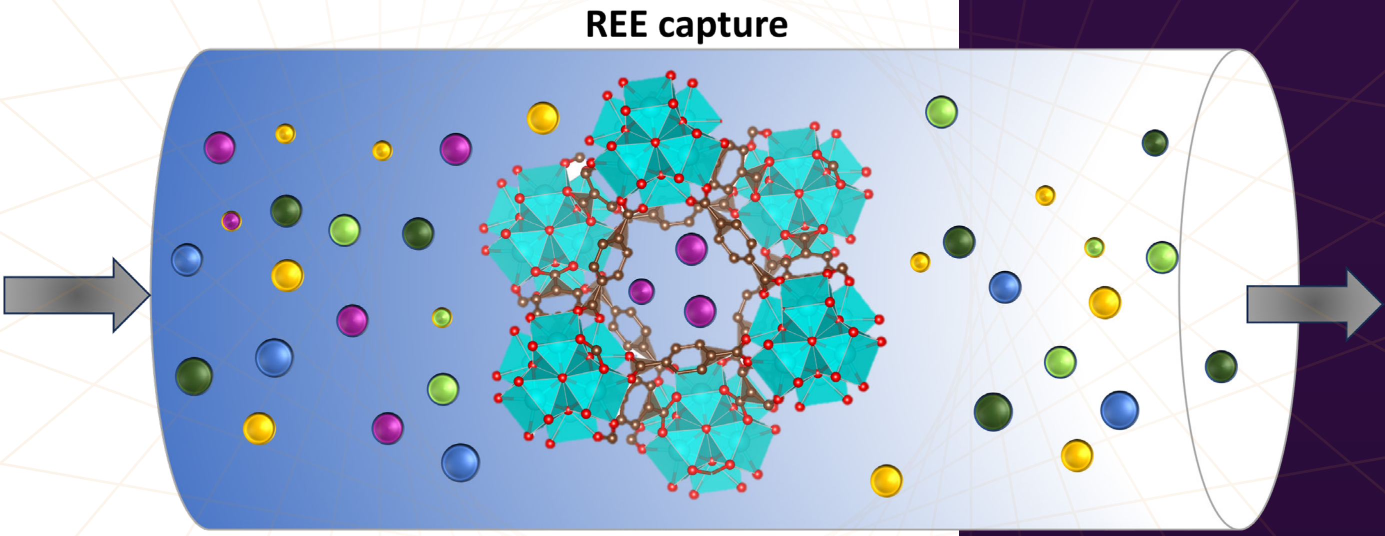
The demand for rare earth elements (REE) is growing, as these materials are crucial for sustainable energy and advanced technologies. However, separating these elements poses significant challenges and can cause environmental harm. This Sandia team has advanced research on porous materials tailored for environmentally friendly REE separations, focusing on metal-organic frameworks (MOF). They discovered the mechanisms by which REEs partition into MOFs and demonstrated strategies to enhance the selectivity of these materials for REEs.

Collaborations with the Sandia National/Regional partner University of Texas at El Paso, Georgia State University, and Temple University supported research on interactions between REEs and MOFs. These findings were presented at the American Chemical Society National Meetings, showcasing innovative REE separation methods and their implications for sustainable technologies. (PI: Anastasia G. Ilgen)

READ MORE > *Chemical Communications*, *Physical Chemistry Chemical Physics*, *ACS Applied Materials and Interfaces*

LEVERAGING NEW TALENT > Several postdocs were trained through this LDRD project, with Jacob Deneff transitioning to a permanent position at Sandia and R. Eric Sikma accepting a tenure-track role at a university.

Sandia researcher Anastasia Ilgen led an LDRD to harness porous materials for safer and more effective rare earth element separations. (Photo by Randy Montoya)

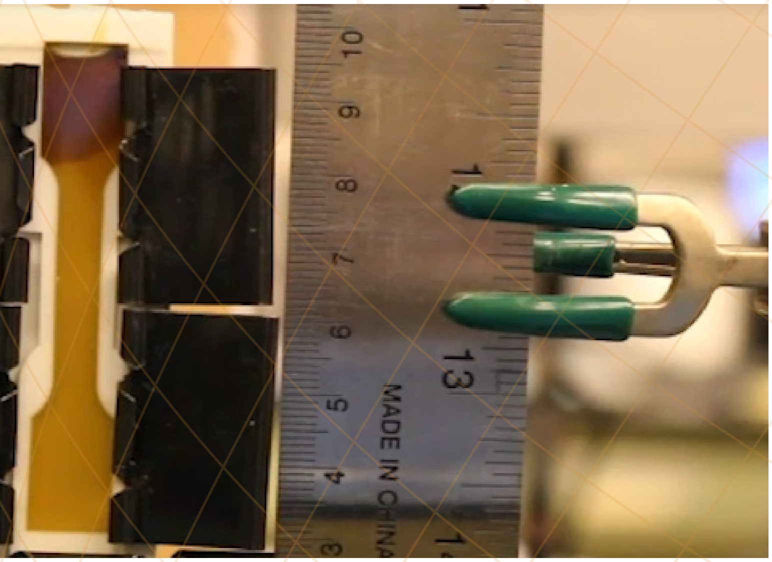


Selective capture of REEs in tailored porous materials

Transforming plastics with on-demand chemical recycling innovations

Improving methods for the manufacture and chemical recycling of plastics is critical. This innovative research done at Sandia embeds the capability to break down plastics directly within the material, allowing for on-demand degradation through an energy-efficient stimulus. This approach is more effective than traditional methods and can eliminate the need for solvents. Additionally, the team's advancements enhance polymerization systems, such as resins for 3D printing, which exhibit exceptional shelf stability without compromising properties.

Efficient recycling of rubber used in tires, electronics, and more



Light-activated, energy-efficient polymerization of a resin into a tough polymer material.

Key collaborations with Professor Paul Kohl at Sandia Alliance partner Georgia Tech and Professors Tim Long and Eileen Seo at Sandia National/Regional partner Arizona State were crucial.

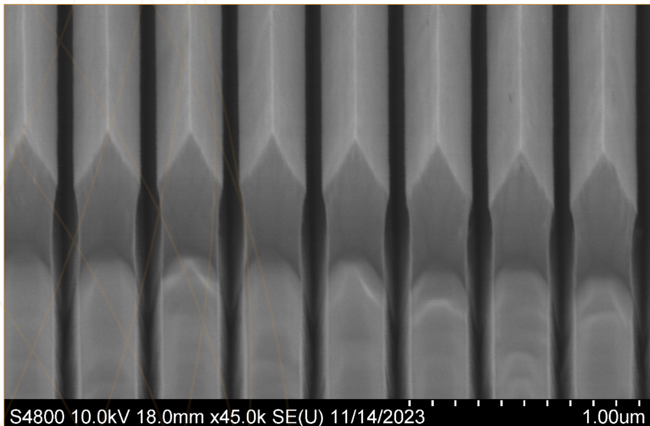
Sandia researchers have published in leading journals and presented at major conferences, highlighting potential applications in national security and consumer applications. Looking ahead, Sandia has secured funding to expand this research and explore commercial partnerships, ensuring continued innovation in polymers.
(PI: Brad H. Jones)

READ MORE > *Advanced Science*, *ACS Applied Materials & Interfaces*, *Journal of Applied Polymer Science*, *ACS Sustainable Chemistry & Engineering*, *Chemical Communications*, *Macromolecules*, *Polymer Chemistry*

LEVERAGING NEW TALENT > Critical contributors included postdocs Samuel Leguizamon, Matthew Warner, and Oleg Davydovich, along with interns Josephine Lewis, Mikayla Romero, and Francesca C'deBaca.

Enhancing quantum sensors for precision navigation/timing without GPS

Sandia researchers are tackling the challenge of using non-planar nano-epitaxial growth of indium gallium nitride semiconductor materials to microfabricate diode lasers that operate in the green-yellow-orange gap, which spans a third of the visible light spectrum. This innovative approach has the potential to develop new quantum sensors that require laser wavelengths in the visible spectrum.

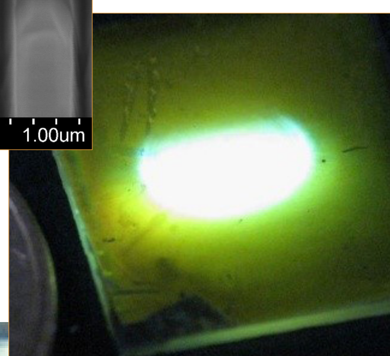


Scanning electron microscope images of indium gallium nitride nano-structured epitaxial growth of yellow light emitters.

Collaboration with University of New Mexico Professor Daniel Feezell and graduate student, Elizabeth DeJong, enriched the team's insights and methodologies in researching gallium nitride-based optoelectronic devices.

Sandia researchers shared their findings through presentations at the Frontiers in Optics Conference and the Conference on Lasers and Electro-Optics. This groundbreaking work holds promise for mission spaces that require precision navigation and timing without relying on Global Positioning System signals. (PI: Darwin Serkland)

LEVERAGING NEW TALENT > Postdoc Stephanie Malek contributed new meta-surface designs and published a conference paper on the meta-surface effects observed in photoluminescence measurements of indium gallium nitride nano-structures.



Bright yellow photoluminescence from non-planar nano-structured indium gallium nitride epitaxial semiconductor crystals.

Sandia teams collaborate at Sandia's Microsystems Engineering, Science and Applications complex, where researchers design, produce and test chips for national security applications.

Advancing superconductors to improve grid-based electrical storage and transmission

The search is on to discover a superconductor that operates near ambient pressure and temperature using superconducting hydrides. While these materials can exhibit high-temperature superconductivity, they typically require extremely high pressures to function. A team at Sandia has implemented novel synthesis methods to explore ways to reduce the formation and stability pressure of these materials.

The potential impact of this research, conducted in collaboration with California State University Northridge and Argonne National Laboratory, includes the development of new materials for lossless power transmission, which could greatly enhance energy efficiency.

Sandia researchers presented at conferences organized by the American Physical Society, American Chemical Society, Materials Research Society, and Electrochemical Society. (PI: Peter Sharma)

READ MORE > *Thin Solid Films*, *Small*, *Fundamental Research and Application of Physical Science*

LEVERAGING NEW TALENT > Key contributors to this research include postdocs Mohana Shivana, Tim Elmslie, and Pinwen Guan and interns Portia Allen, Harini Gunda, Katlyn Grimm, Katty Kaydanik, and Nick Porcellini.

Microsystems Engineering, Science and Applications (MESA) team members at Sandia manufacture semiconductor wafers under orange lighting to prevent light exposure of photoresist, similar to developing photography film in a dark room.

Developing techniques to predict fluid viscosity in extreme environments

This project is developing experimental and theoretical techniques to accurately measure and predict the viscosity of fluids in extreme pressure and temperature conditions. Thus far, LDRD researchers have conducted scoping experiments at the STAR facility to demonstrate the basic feasibility of the experimental method, implemented a physical viscosity treatment in the magnar hydrocode, developed a viscosity analysis toolkit from atomistic simulations, and validated the results against results from peer institutions at a workshop over summer 2023.

Sandia team members, including graduate student Sammi Rosenfeld and Alisha Clark, an assistant professor at Sandia National/Regional partner University of Colorado Boulder, are carrying out independent and complementary viscometry experiments at low pressure which provide crucial constraints on viscosity in this regime.

Results were presented at the Z Fundamental Science Workshop, the Lunar and Planetary Science Conference, and the American Geophysical Union Fall Meeting. The results of this project can potentially be used to better understand instability growth in HED experiments.
(PI: Joshua Townsend)

READ MORE > *Physics of Plasmas (1), (2)*

Advancing quantum computing with breakthroughs in atom interactions and detection

Developing a neutral-atom quantum computing processor with high computational capacity and fidelity requires deeper understanding in fundamentals of real atoms and the energy science in atom-atom interactions.

In this three-year project, LDRD researchers have made several important breakthroughs. They achieved the world-best low-atom-loss 0.9(2)%, high-fidelity 0.9991(2) qubit state detection technique. They also fabricated the first-ever UV photonic integrated circuits functioning at 320 nm and demonstrated new quantum control protocols and novel leakage detection unit in quantum computing using the Rydberg-enabled interaction.
(PI: Yuan-Yu Jau)

READ MORE > *arXiv (1) (2), Physical Review A (1) (2)*

Sandia researcher Yuan-Yu Jau led a three-year LDRD project that made several important breakthroughs in developing a neutral-atom quantum computing processor with high computational capacity and fidelity.

COOL FACT > Success of this research will enable a powerful scientific tool, a practical quantum computer, that will greatly benefit many types of research that are involved with quantum physics/ chemistry and will solve the hard problems in security applications.

LEVERAGING NEW TALENT > Postdocs Saurabh Pandey and Coleman Burdette Cariker assisted in the work on this project.

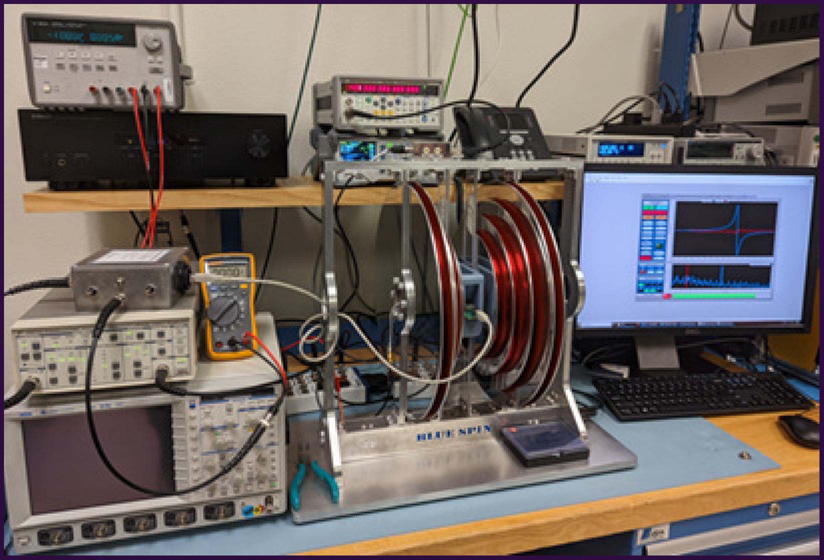
Improving semiconductor reliability through a greater understanding of degradation mechanisms

Sandia researchers are studying the reliability of metal oxide semiconductor field effect transistors, specifically time-dependent dielectric breakdown. Despite decades of research, the exact mechanisms behind this issue remain unclear. The team employed electrically detected magnetic resonance techniques alongside electrical measurements to deepen their understanding of these mechanisms.

Sandia has gained valuable insights into the development of atomic-scale point defects and has developed new experimental capabilities applicable to semiconductor technologies. Sandia researchers hosted two Penn State students for summer research, fostering interest in future careers at Sandia.

The team is preparing to publish their findings and has presented their novel approach at the Rocky Mountain Conference on Magnetic Resonance. They have also submitted an abstract to the International Reliability Physics Symposium, focusing on defects responsible for dielectric breakdown.

This research enhances Sandia's reliability models as technology scales and lays the groundwork for new projects investigating atomic-scale defectivity in emerging semiconductor architectures and materials. (PI: Colin G. McKay)



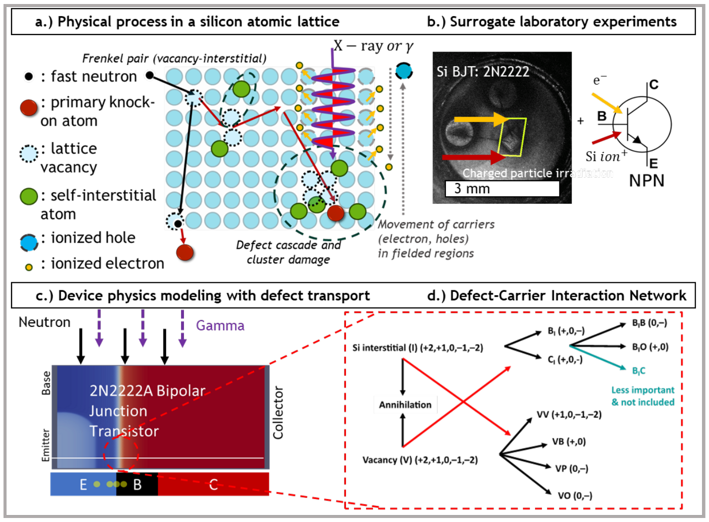
New low-field electron spin resonance spectrometer built at Sandia as part of this project.

Transforming research on combined neutron and gamma irradiation effects in microelectronics

Understanding how the radiation survivability and response of silicon and gallium arsenide-based microelectronics differ in combined radiation environments is important for microelectronics qualification. This LDRD project focuses on modeling the effects of combined neutron and photon (gamma and X-ray) irradiation on the current amplification of bipolar transistors and circuit behavior. Accurately modeling neutron displacement damage and gamma/X-ray ionization requires handling over 100 defect and carrier interactions, significantly modified in a combined environment. Surrogate ion and electron irradiation were performed at Sandia's Ion Beam Laboratory.

The collaborative LDRD team, which contributed to two doctoral dissertations from the Sandia Alliance partners UT Austin and the University of New Mexico, developed new computational models and gathered experimental data to support ongoing research. Future projects will explore additional radiation processes and utilize artificial intelligence for predictions. (PI: Josh Michael Young)

LEVERAGING NEW TALENT > Student intern Nick Asper helped computationally model ion and neutron transport for this project. Asper is completing his PhD at UT Austin in mechanical engineering based on neutron physics in gallium arsenide. Collin Burt experimentally evaluated a new radiation tolerant circuit, QUASAR, for this LDRD. Burt is completing his PhD in electrical engineering from UNM based on the design and evaluation of QUASAR.



Simulated interactions in a silicon bipolar junction transistor under neutron and gamma irradiation conditions.

PROJECT HIGHLIGHTS –

WORKFORCE DEVELOPMENT

Sandia's LDRD program enables principal investigators and research teams to collaborate with other national laboratories, academic institutions, and industry partners to revolutionize what is possible in science and engineering. This not only develops Sandia's workforce, but it also grows the nation's technical research capabilities overall, and even contributes to the economy.

The highlights in this section are only a small subset of the impacts that have been made in 2024 through LDRD, but they give a glimpse of how significant the program is to the country and to the world.

PRESTIGIOUS FELLOWSHIPS, APPOINTMENTS AND MEMBERSHIPS

National Academy of Engineering, National Academy of Inventors Fellow, DOE NNSA Silver Medal Award, DOE Secretary Honor Award

Tina Nenoff has led ***A DOZEN LDRD PROJECTS*** *at Sandia, and she credits her success to early parental support, exceptional mentors, and a passion for impactful research.*
(Photo by Lonnie Anderson)

It's been a busy year for Sandia Fellow **Tina Nenoff**. Nenoff has been elected as a member to the National Academy of Engineering for her groundbreaking research in nanoporous materials and their applications in societal and national security challenges. For her exceptional achievements as an inventor, Nenoff was also elected to the National Academy of Inventors. In 2024, she was also presented with multiple DOE-level awards including the DOE NNSA Silver Medal Award for her service, execution, and impact as Science Advisor for the NA-1 Administrator (Jill Hruby), and the DOE Secretary Honor Award for her role on the AI Export Control Team. The Secretary's Honor Awards are the pinnacle of recognition bestowed by the Secretary to individuals or groups for their outstanding contributions in support of DOE's mission.

With over 190 peer-reviewed articles, four book chapters, and 17 U.S. patents, Nenoff has made significant contributions, including the use of crystalline silicotitanates molecular sieves to cleanse 160 million gallons of radioactive water at Fukushima Daiichi nuclear power plant. Her recent work focuses on metal-organic frameworks for absorption materials and low-power sensors targeting caustic gases.

Former Sandia Deputy Chief Research Officer and current Engineering Sciences Center Director Basil Hassan, left, passes the AIAA presidential gavel to Sandia Deputy Labs Director Laura McGill on April 27, 2022, at the institute's Awards Gala in Washington, D.C. (Photo by American Institute of Aeronautics and Astronautics)

American Institute of Aeronautics and Astronautics Distinguished Service Award

Basil Hassan, Director of Sandia's Engineering Sciences Center and former Deputy Chief Research Officer, received an AIAA Distinguished Service Award for more than three decades of exemplary service at the national, technical, and regional levels, as well as with publications, honors and awards, and the AIAA Foundation. Hassan's dedicated and influential work in aerospace started at Sandia in 1993 where he researched aerodynamics and aerothermodynamics of high-speed flight vehicles, drag reduction for ground transportation vehicles, and high-velocity oxygen fuel thermal sprays. In 2003, he supported NASA in determining the cause of the space shuttle Columbia accident. This premier AIAA award exemplifies the relentless pursuit of excellence among a select group whose contributions merit the highest accolades in the field.

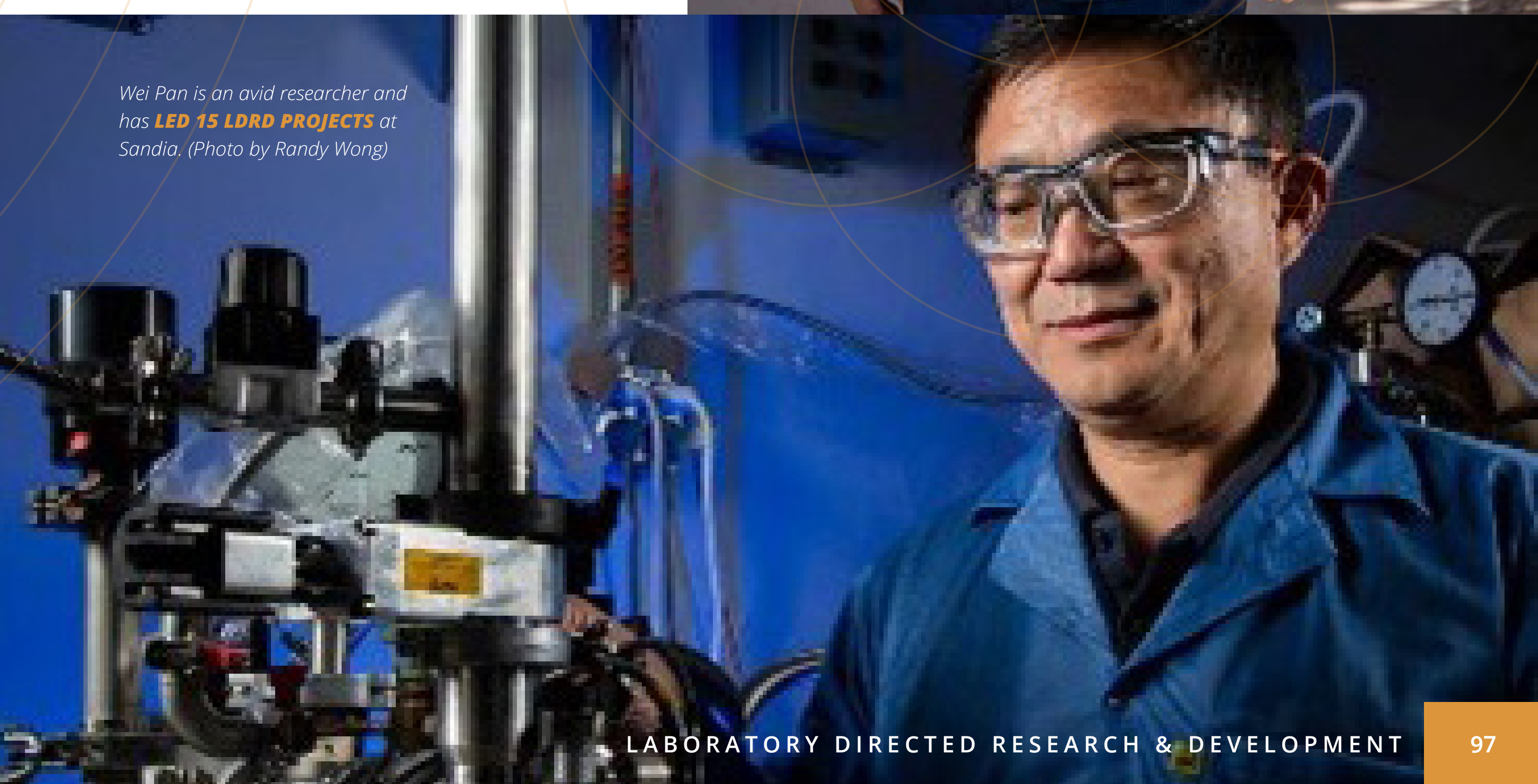
American Physical Society Fellow

Wei Pan was honored with a Fellow appointment from the *American Physical Society* for his "discovery of several unconventional fractional quantum Hall states and his innovative experiments exploring the excitonic insulator phase in InAs/GaSb, Majorana particles, topological superconductivity, and Leggett modes in Dirac semimetals." His work on the fractional quantum Hall effect has significant implications for fault-tolerant quantum computing. Wei Pan's journey from theory to experimentation, supported by his mentors and colleagues, and his passion for scientific discovery have been key to his achievements. His contributions to the field of condensed matter physics and his dedication to advancing quantum phenomena were recognized by the Division of Condensed Matter Physics of APS.

2024 Materials Research Society Medal

Sandia researcher **Hongyou Fan** was awarded the prestigious 2024 Materials Research Society (MRS) Medal, recognizing his innovative approach to synthesizing nanomaterials using pressure instead of traditional chemical solutions. The MRS Medal is the society's highest accolade, celebrating significant advances expected to greatly impact progress in materials science. His work is described as "pioneering pressure-induced nanomaterial synthesis and characterization for materials exploration and discovery." In a Sandia news article, Fan emphasizes the importance of tackling significant challenges. "Identify problems that matter," he said. "Look for gaps in existing knowledge that haven't been addressed yet."

*Hongyou Fan, who has acted as PI on **10 LDRD PROJECTS**, suggests that researchers keep an eye on emerging trends as these can help pinpoint areas ripe for innovation.*

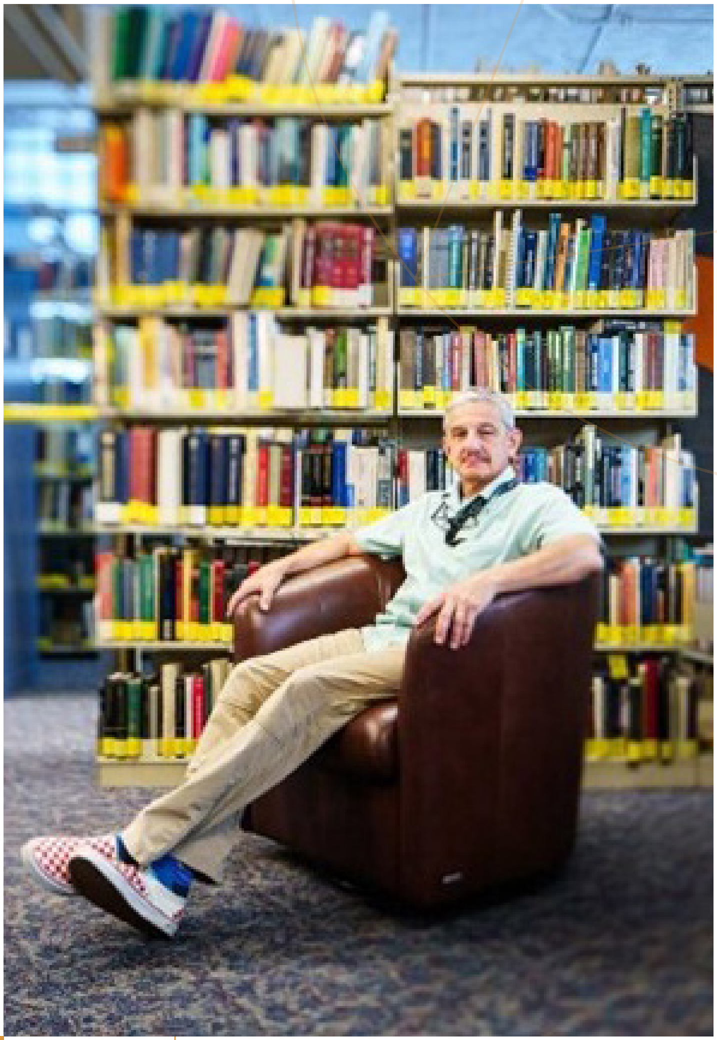


*Wei Pan is an avid researcher and has **LED 15 LDRD PROJECTS** at Sandia. (Photo by Randy Wong)*

Society for Industrial and Applied Mathematics Fellow

Rich Lehoucq was chosen as a *SIAM Fellow* for his significant contributions to the fields of applied mathematics, computational science, and data science. His work spans nonlocal modeling, numerical linear algebra, continuum mechanics, and the applications of probability to optimization and high-dimensional data analysis. Lehoucq's innovative approach to extending the edges of these fields has led to the development of better tools for engineers, particularly in modeling fractures. His career at Sandia, shaped by mentorship and a willingness to explore new ideas, has included publishing over 75 papers, co-authoring a book, and contributing to international conferences and journals.

Rich Lehoucq's resilience and enthusiasm for learning have been key to his success and recognition by the Society for Industrial and Applied Mathematics. He has led ***SIX LDRD PROJECTS*** *during his career at Sandia. (Photo by Craig Fritz)*



Institute of Electrical and Electr

Three accomplished Sandia researc IEEE Fellow recognition is awarded t

Michael Ropp has ***LED THREE LDRD PROJECTS*** *at Sandia, with one still ongoing. This IEEE Fellow award honors his lifetime achievements and his deep understanding of electrical engineering challenges and solutions.*

Michael Ropp received the IEEE Fellow award for his significant contributions to improving the resiliency of the electrical grid, particularly with the integration of renewable energy sources like rooftop solar panels and wind turbines. His pioneering work on detecting and preventing unintentional islanding, which is now foundational for 75% of inverters on the grid, and his research on using time-synchronized voltage measurements (synchrophasors) for unintentional islanding detection, have been instrumental in advancing grid stability and reliability.

> *"LDRD was an indispens Toolbox (SHEPS Toolbox way to keep the lights o*

ronics Fellows

hers were elected as IEEE Fellows in 2024. This is a significant achievement since the to fewer than 0.1% of IEEE members annually.

Before becoming Pulsed Power Sciences director and then Sandia's Deputy Chief Research Officer, Dan Sinars acted as PI on ***FOUR LDRD PROJECTS****.*

Dan Sinars was promoted to IEEE Fellow for contributions of radiography diagnostics and magneto-inertial fusion. Sinars, who went from proposing experiments on Sandia's Z machine to directing the facility, to his current position as Sandia's Deputy Chief Research Officer where he helps direct R&D at Sandia, was cited for his "pioneering development of seminal X-ray diagnostics and their innovative application to Z-pinch implosions that transformed the experimental capabilities on the Z pulsed power facility and enabled novel, record-breaking platforms supporting our nation's nuclear security."

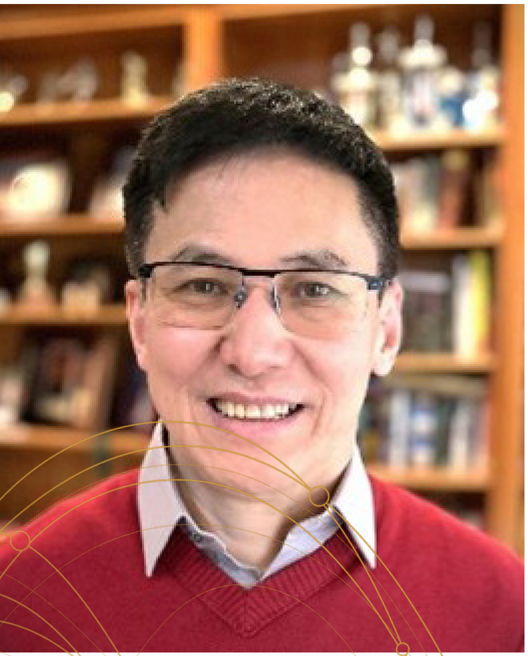
New IEEE Fellow Jeff Tsao recently completed his ***SECOND LDRD PROJECT****. (Photo by Craig Fritz)*

Jeff Tsao, a new IEEE Fellow, has a career spanning two national laboratories and brief stints in industry and academia. He has focused on optoelectronics, with more than two decades in solid state lighting (SSL). He was elected for contributions to semiconductor-epitaxy and for his previously mentioned research in SSL technologies. Tsao also served on DOE committees that road-mapped possible paths for improved LED lighting and came up with new ways of improving LED efficiencies and usefulness. Although his SSL work was largely programmatic and of a community service nature, the published parts have accumulated 1,750 citations.

sable way to get started on the Self-Healing Electric Power Systems x), which is turning out to be an extremely interesting and exciting n when things go really wrong."

– Michael Ropp

Microscopy Society of America Fellows



Ping Lu was elected as a Microscopy Society of America (MSA) Fellow for "significant and noteworthy contributions to the development and applications of atomic-scale electron microscopy and microanalysis to contemporary materials problems." The designation "MSA Fellow" recognizes individuals who have received the Society's Distinguished Scientist Awards or are senior distinguished members who have significantly contributed to the advancement of microscopy and microanalysis through scientific achievement and service. Ping Lu is a distinguished materials scientist whose work within the LDRD program has significantly advanced the field of materials characterization. Utilizing advanced electron microscopy techniques, Lu has researched the microstructural and chemical properties of materials at the atomic and nanoscale levels.

Ping Lu's research including pioneering in situ electron microscopy, provides real-time insights into material behavior under various conditions, such as heating and mechanical stress. Lu has ***LED FOUR LDRD PROJECTS*** *since coming to Sandia.*

John and Samuel Bard Award

Jen Gaudioso, Center Director for Computing Research, was awarded the John and Samuel Bard award, which honors scientists whose achievements demonstrate breadth of concern and depth of commitment. This is Bard College's highest award for science. Gaudioso has served on two National Academies Committees addressing biodefense issues and has authored numerous peer-reviewed articles, book chapters, and two books. She holds PhD and master's degrees in physical chemistry from Cornell University and a bachelor's degree in chemistry from Bard College and came to Sandia in 2002 as a postdoctoral fellow. In 2024, *Gaudioso testified before Congress* on how scientists at U.S. national laboratories are poised to elevate artificial intelligence to address some of the most complex scientific and national security challenges.

Jennifer Gaudioso, who has ***LED TWO LDRD PROJECTS*** *at Sandia, is shown testifying during a Senate committee hearing on June 4, 2024. (Image captured from Congressional hearing video)*

EARLY CAREER AWARDS AND HONORS

DOE OFFICE OF SCIENCE EARLY CAREER RESEARCH PROGRAM AWARDS

Sandia scientists Mitchell Wood and Gianluca Geraci received 2024 DOE Office of Science Early Career Research Program awards. Each will receive $2.75 million over five years to support their research in Fusion Energy Sciences and Advanced Scientific Computing Research. They were selected from a competitive pool of applicants, with 91 awardees chosen through peer review by scientific experts.

Mitch Wood, a computer scientist in Sandia's computational multiscale department, received a DOE Early Career Research Award for his research on materials science and machine learning. His work spans plasma-facing materials, multiscale modeling of shock compression, and physics-inspired machine learning. With the award funding, Wood plans to study how materials withstand radiation damage and develop new methods for designing fusion power plants. His project, titled "Mechanisms of Non-Equilibrium Ion Dynamics in Radiation Tolerant Alloys," is focused on using new data-science methods to capture physical processes that have been historically computationally expensive.

Computer scientist Mitch Wood has ***LED TWO LDRD PROJECTS*** *at Sandia.*

Gianluca Geraci, a computational scientist in Sandia's optimization and uncertainty quantification department, received the DOE Office of Science Early Career Research Award for his work in scientific machine learning for predictive computational science. His research focuses on uncertainty quantification, multifidelity methods, data-driven approaches, and related fields. Geraci's awarded project, "Enabling Scientific Data-Driven Modeling for Heterogeneous, Multi-Model, Massive, and Distributed Datasets," aims to develop mathematical and algorithmic tools for scientific machine learning to advance DOE applications. This award will support his research for the next five years, allowing him to build a team and contribute to the scientific mission of the DOE and Sandia.

Computational scientist Gianluca Geraci has ***ACTED AS PI ON TWO LDRD PROJECTS*** *while working at Sandia.*

Presidential Early Career Awards for Scientists and Engineers

The Presidential Early Career Awards for Scientists and Engineers (PECASE) is the highest honor bestowed by the U.S. government on outstanding scientists and engineers beginning their independent careers. The PECASE awards aim to encourage innovation, raise awareness about careers in scienzce and engineering, and connect research with national goals.

Four Sandia researchers won these prestigious awards in 2024.

Daniel Ruiz joined Sandia in 2017 as a Truman Fellow and received his PECASE award from NNSA. Through his research, he has been studying magneto-inertial-fusion technologies to achieve high fusion yields in the laboratory. His contributions are key to Sandia's advocacy for a future pulsed-power facility for long-term stewardship of our nation's nuclear deterrent. Ruiz is the lead designer for several experiments at the Z facility and is dedicated to community outreach by mentoring students, organizing sessions at scientific meetings, peer-reviewing articles in journals, and reviewing proposals for national science programs.

PECASE winner Daniel Ruiz is ***PI OF HIS THIRD LDRD PROJECT*** *at Sandia*

Gwen Voskuilen has been recognized for her contributions to next-generation high-performance computer architecture and was awarded a PECASE from NNSA. Her research centers on innovative processor and memory system technologies, in addition to advancements in computer hardware simulation. Voskuilen joined Sandia in 2014 after receiving her PhD in Computer Engineering from Purdue University.

PECASE winner Gwen Voskuilen currently leads the Structural Simulation Toolkit simulation project, is involved in a number of efforts around hardware simulation and performance analysis and is in her ***THIRD YEAR AS PI OF AN LDRD PROJECT****.*

Caroline Winters is currently a researcher at the Thermal Test Complex, focusing on Fire Science and Technology. She develops tools to measure temperatures in challenging conditions and combines knowledge from material science, engineering, and lasers. Winters, who began at Sandia in 2015 as a graduate student intern, leads teams to support important projects related to nuclear safety and extreme environments.

Caroline Winters received her PECASE award from NNSA and has ***LED FOUR LDRD PROJECTS*** *at Sandia, with one still ongoing.*

Peter Bosler was awarded a PECASE award from DOE. His research focuses on simulation methods for multiscale applications, where complex interactions across various scales affect the dynamics. For example, the characteristics of individual raindrops can affect cloud properties, leading to small storms or large cyclones. Modeling these scales is mathematically and computationally challenging.

PECASE winner Daniel Ruiz is PI of his ***THIRD LDRD PROJECT*** *at Sandia.*

FY24 HRUBY AND TRUMAN POSTDOCTORAL FELLOWSHIPS

JILL HRUBY POSTDOCTORAL FELLOWSHIP

The LDRD-funded Jill Hruby Postdoctoral Fellowship was established in 2017 to encourage outstanding women with PhDs in technical fields to consider leadership in national security. Jill Hruby served as the Under Secretary of Energy of the United States from 2021-2025, was the first woman to lead a national security laboratory, and served as Sandia's director from 2015 to 2017.

Samantha Jaszewski – FY24 Hruby Fellow

Samantha Jaszewski is researching computer memory based on ferroelectric materials, specifically hafnium oxide, during her fellowship. Hafnium oxide, present in computer chips, can enable further miniaturization of components and increase computing efficiency while lowering energy needs. It also has the potential to withstand harsh radiation environments, important for national security applications. Her goal is to understand the material's performance under radiation and its fundamental limits. She graduated from Boston College with a bachelor's in chemistry and completed her doctorate in materials science and engineering at the University of Virginia in 2023. Inspired by her adviser, former Sandian Jon Ihlefeld, Jaszewski pursued a fellowship at Sandia to explore working at a national lab.

FY24 Hruby Fellow Samantha Jaszewski is currently PI of an ***ACTIVE LDRD PROJECT*** *at Sandia. (Photo by Tom Cogil)*

FY24 Hruby Fellow Hannah Stroud values the support and knowledge of her team at Sandia. She is leading an ***ONGOING LDRD PROJECT****.*
(Photo by Lonnie Anderson)

Hannah Stroud is researching the incorporation of roughness features into fluid and ablation models to enhance reentry vehicle performance. With bachelor's, master's, and doctorate degrees in aerospace engineering from Texas A&M University, her graduate research focused on how forces from fluids can remove material from structures. Her current work at Sandia involves understanding the aerodynamic effects of rough surface geometries produced during the ablation process, which is crucial for developing better hypersonic systems. Inspired by her internship experience at Sandia, Stroud sought the fellowship to choose her research path and learn from leading experts.

HARRY S. TRUMAN POSTDOCTORAL FELLOWSHIP

Sandia established the Harry S. Truman three-year fellowship, funded by LDRD, to attract the nationally recognized PhD scientists and engineers. Truman Fellows conduct independent groundbreaking research that supports Sandia's national security mission.

Truman Fellow Matthew Barry is currently PI for an ***ACTIVE LDRD PROJECT*** *at Sandia.*

Matthew Barry is developing a machine-learning framework for multiscale modeling of atomic systems during his fellowship. This framework will enable development of reduced-order material structure-property relationships to speed up or bypass expensive physics simulations, facilitating the design and discovery of novel multifunctional materials for national energy and defense missions. Building on tools from his PhD, he and his team at Sandia are enhancing these tools to study specific materials. With prior fellowship experience from the National Science Foundation and NASA, Barry values the freedom to explore research topics and apply his findings to Sandia's missions. He holds a master's in mathematics and a doctorate in mechanical engineering from Georgia Tech.

Jonathan Paras is making breakthroughs in metal manufacturing at Sandia. His fascination with metals began in high school and led him to study materials science and engineering at MIT, where he completed his bachelor's and doctoral degrees. Paras' research focuses on the thermodynamic behavior of metal alloys at high temperatures to predict their response under extreme conditions and design new manufacturing processes. Inspired by the metallurgical research of the Manhattan Project, he aims to revolutionize conventional manufacturing.

Truman Fellow Jonathan Paras is currently ***LEADING A SANDIA LDRD PROJECT TEAM****. His work contributes to Sandia's mission by bringing fresh perspectives and innovative approaches to critical projects. (Photo by Lonnie Anderson)*

PROFESSIONAL SOCIETY AND CONFERENCE AWARDS

2024 Women Chemists Committee Rising Star Award

Dorina Sava Gallis was honored with the 2024 Women Chemists Committee Rising Star Award by the American Chemical Society, recognizing her outstanding promise and contributions to the field. In her 14 years at Sandia, Sava Gallis has accumulated over a dozen U.S. patents, authored or co-authored more than 60 technical publications, and is recognized as a world expert in nanoporous materials, particularly metal-organic frameworks. Her work spans various applications, including environmental remediation, gas storage, energy storage, and advanced therapeutic countermeasures. Sava Gallis enjoys assembling multidisciplinary research teams to tackle national security challenges and has become adept at technology transfer and commercialization. She holds a bachelor's degree in materials science and engineering and a doctorate in chemistry.

Dorina Sava Gallis is the first Sandia scientist to receive the 2024 Women Chemists Committee Rising Star Award. Sava Gallis has led ***SEVEN LDRD PROJECTS****.*

Society of Women Engineers International Ignite Award

Erica Redline, who received the SWE international Ignite Award, has ***LED FOUR LDRD PROJECTS*** *at Sandia. (Photo by Craig Fritz)*

Sandia engineer **Erica Redline** was honored with the Society of Women Engineers international Ignite Award for her advocacy and mentorship of women in STEM. With over 10 years at Sandia, Redline has advanced polymer science, developed next-generation materials, and holds four U.S. patents with five more pending. She has inspired hundreds of students to explore STEM fields and has been involved in various outreach activities, including collaborating with Girl Scouts, judging the New Mexico Science Bowl, and leading hands-on programs. Redline has also worked with the University of Minnesota's CAUSE and mentored students through the University of New Mexico's Upward Bound Program.

Black Engineer of the Year Awards Most Promising Engineer in Industry Award

System engineer and researcher Nicole Jackson received the BEYA Most Promising Engineer in Industry Award in 2024. She has ***LED TWO LDRDS*** *at Sandia.*

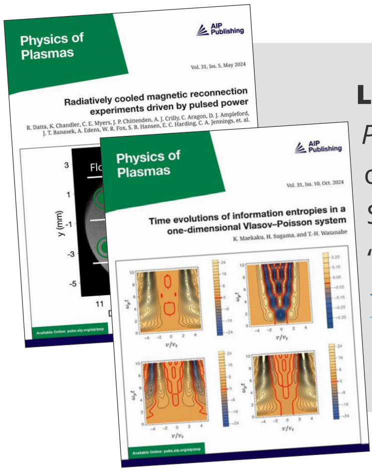
Nicole Jackson, a systems engineer and senior member of Sandia's technical staff, received the Black Engineer of the Year Awards (BEYA) Most Promising Engineer in Industry Award. Her work focuses on helping communities adapt to atmospheric change and sustainably manage natural resources by studying past and projected natural hazards and their impact on infrastructure. In her nearly five years at Sandia, Jackson has built a strong professional reputation and was nominated by the United States Global Change Research Program to the Integrated Hydro-Terrestrial Modeling Coordinating Group. She is also dedicated to increasing diversity and inclusion in civil engineering by mentoring STEM students at various educational levels.

Black Engineer of the Year Science Spectrum Trailblazer Award

Anthony Sanders is a systems engineer and R&D manager for one of Sandia's National/Regional Partnership departments aligned with Securing Top Academic Research & Talent at HBCUs. He received the Black Engineer of the Year (BEYA) Science Spectrum Trailblazer Award in 2024 and uses his vast technical background to help develop and foster key collaborations between Sandia and strategic university partners.

BEYA Science Spectrum Trailblazer Award recipient Anthony Sanders holds a pivotal role at Sandia. The team he leads helps build a more robust talent pipeline and enhance research ties between key academic institutions and Sandia.

JOURNAL COVERS & EDITOR'S PICKS



Lucas Stanek and his LDRD team published two papers in *Physics of Plasmas*, both receiving the "Editor's Pick" designation. These articles highlight collaborations with all three NNSA laboratories and various university partners. Stanek has **LED ONE LDRD PROJECT** that is ongoing.

"ETHOS: An automated framework to generate multi-fidelity constitutive data tables and propagate uncertainties to hydrodynamic simulations"

"Charged particle transport coefficient challenges in high energy density plasmas"

PI Adam Darr and his team had their work published in the high impact publication in *Physical Review Letters*, "Theoretical Coupling of Free-Flowing Ions and Magnetically Insulated Electrons," and their article, "Mutually magnetically insulated two-species Brillouin flow," received Editor's Pick in *Physics of Plasmas*. Darr has **LED TWO LDRD PROJECTS** at Sandia with one ongoing.

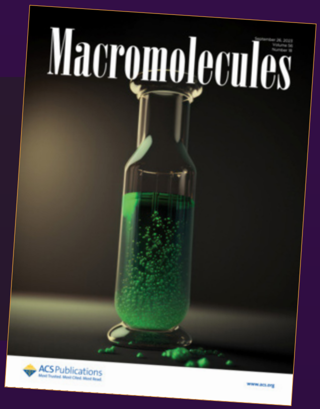
Kimberly Butler and her LDRD team's work resulted in two high impact publications, with one recognized on the cover of *Journal of the American Chemical Society* for the article, "Quest for Multifunctionality: Current Progress in the Characterization of Heterometallic Metal–Organic Frameworks." This article showcased the expertise across Sandia and across projects on the use and understanding of heterometallic Metal-Organic Frameworks. Butler has **LED FIVE LDRD PROJECTS** at Sandia, with one ongoing.

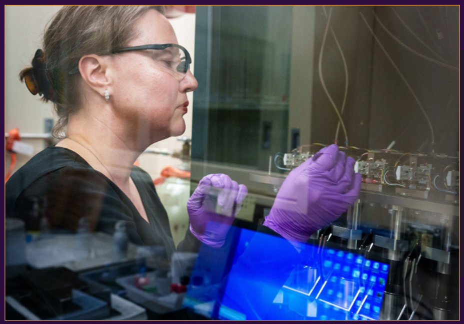
In partnership with Purdue University, **PI Tuan Ho** and his LDRD team published research in *The Journal of Physical Chemistry Letters*, including articles on *Hydrophobic Nanoconfinement Enhances CO2 Conversion to H2CO3* and *Control of the Structural Charge Distribution and Hydration State upon Intercalation of CO2 into Expansive Clay Interlayers*. Their work received a 2024 R&D 100 Award. Ho has **LED THREE LDRD PROJECTS** at Sandia, with one ongoing.

PI **Diana Bull** and her team had their work on the LDRD CLDERA Grand Challenge project featured in the *NY Times*. The image below shows a balloon launch from near Lauder, New Zealand that is part of a global atmospheric surveillance system. Bull has **LED TWO LDRD PROJECTS** at Sandia and **ONE LDRD GRAND CHALLENGE**, which encompasses numerous associated LDRD projects.

PI **Samuel Leguizamon** and his team published journal article, "Monodomain Liquid-Crystal Elastomer Lattices for Broad Strain-Rate Mechanical Damping," in *Advanced Engineering Materials*. The results from their ongoing project shows promising outcomes. Leguizamon has **LED TWO LDRD PROJECTS** at Sandia, with one ongoing.

Brad Jones and his LDRD team had their work featured on the cover of Macromolecules, "Encapsulated Transition Metal Catalysts Enable Long-term Stability in Frontal Polymerization Resins." Jones has **LED 10 LDRD** projects at Sandia with two ongoing.





Sandia geochemist and LDRD PI Anastasia Ilgen works on a vapor sorption analyzer used for characterizing the chemistry of porous solids such as metal-organic frameworks. Ilgen and her team designed MOFs for selectively purifying rare-earth elements. (Photo by Craig Fritz)

Anastasia Ilgen and her LDRD team focused their research on cleaner ways to purify critical metals. Their work resulted in multiple published papers and two journal covers. She has **ACTED AS PI FOR FOUR LDRD PROJECTS** at Sandia.

ABSTRACT

This report provides an assessment of the value of the LDRD program to Sandia National Laboratories during fiscal year 2024.

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