



Laboratory Directed Research and Development

Science & Technology Highlights
Lawrence Livermore National Laboratory

LDRD
2024

THE LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROGRAM AT THE LAWRENCE LIVERMORE NATIONAL LABORATORY

invests in bold, high-impact research that advances national priorities and scientific frontiers. It empowers LLNL scientists, engineers, and early-career researchers to pursue innovative ideas, build new capabilities, and grow professionally through hands-on discovery.

The projects featured throughout these pages showcase how LDRD fuels breakthroughs while strengthening the Lab’s world-class workforce and impact in the four mission areas: **Nuclear Deterrence, Threat Preparedness and Response, Energy Security, and Multi-Domain Deterrence.**

These LDRD project highlights include significant work, ranging from foundational research to applied research, pursuing cutting-edge science, technology, and engineering in areas critical to LLNL’s missions.

“

LDRD-funded projects make key contributions in a broad range of science and technology areas, often establishing the foundation for new programmatic directions.

”

-DOUG ROTMAN, LDRD PROGRAM DIRECTOR

CONTENTS

Advanced Materials and Manufacturing	1
High Performance Computing, Simulation, and Data Sciences	3
High Energy Density Science	5
Earth and Atmospheric Sciences	7
Lasers and Optical Science and Technology	9
Nuclear, Chemical, and Isotopic Science and Technology	11
Bioscience and Bioengineering	13
Stockpile and Enterprise Transformation	15
Bio Resilience	17
Earth System Resilience	19
Strategic Advantage	21
LLNL LDRD Metrics By the Numbers FY24	23

Advanced Materials and Manufacturing

Advanced computing enhances manufacturing of high explosive designs

Explosions create extreme environments where material mixing may result in hydrodynamic instabilities. Such instabilities alter explosive processes; understanding such instabilities presents a grand challenge experienced across many scientific fields, including astrophysics and combustion. To address the challenges in controlling these instabilities, LLNL employed artificial intelligence (AI) and machine learning (ML) to explore new, computationally optimized designs.

The use of additive manufacturing — 3D printing — made it possible for researchers to rapidly realize even the most radical AI-designed explosive components that would otherwise be considered “impossible” to create using traditional manufacturing methods. Results will be used in controlling material deformation in complex hydrodynamics, shockwave physics, and energetic materials.

MISSION SUPPORT

By harnessing the disruptive potential of coupling AI and AM, these advances are allowing LLNL to understand and control extreme states of matter in ways that open up new avenues of scientific discovery and **mission applications**.



Jon Belof
Principal Investigator



“

The flexibility and vision provided by LDRD enabled us to rapidly prototype and test innovative, AI-driven designs that simply couldn't be realized with conventional methods. This work is opening new frontiers in controlling material deformation and shockwave physics.

— Jon Belof, PI

”



“

With LDRD, you can pursue high-risk research pressure-free, so you can focus on the deep thinking that drives impactful outcomes. Together with our collaborators, we’re charting a path toward intelligent software that self-optimizes and continually boosts performance.
—Konstantinos Parasyris, PI

”

Revolutionary tool speeds up GPU programs for scientific applications

An LLNL-led team has developed a method for optimizing application performance on large-scale graphics processing unit (GPU) systems, providing a useful tool for developers running on GPU-based massively parallel and distributed machines.

The LLNL-developed mechanism is called Record-Replay (RR), which speeds up applications on GPUs by recording how a program runs on a GPU and then replaying that recording to test different settings and finding the fastest way to run the program. It can be used to improve the performance of OpenMP GPU applications and helps “autotune” large offload applications, thus overcoming a major bottleneck for speed in scientific applications.

MISSION SUPPORT

The approach developed in this GPU technology yields an agnostic framework which can be used to accelerate simulation results across all LLNL missions: **Nuclear Deterrence, Threat Preparedness and Response, Energy Security, and Multi-Domain Deterrence.**

High Performance Computing, Simulation, and Data Sciences

Konstantinos Parasyris
Principal Investigator



High Energy Density Science

Magnesium oxide undergoes dynamic transition when it comes to super-Earth exoplanets

LLNL has unlocked new secrets about the interiors of super-Earth exoplanets, potentially revolutionizing our understanding of these distant worlds and extending our understanding of materials at extreme conditions. The focus of this work, magnesium oxide (MgO), a crucial component of Earth's lower mantle, is believed to play a similar role in the mantles of massive rocky exoplanets.

LLNL's unprecedented approach combines laser-shock compression with simultaneous pressure, crystal structure, temperature, microstructural texture, and density measurements to pinpoint the pressure required for transition.

MISSION SUPPORT

This pioneering work enables direct exploration of matter under the extreme pressures and temperatures, providing critical insights that broaden the frontiers of planetary sciences and push the boundaries of **Energy Security** and **Threat Preparedness and Response**.



Saransh Soderlind
Principal Investigator

“These were pretty novel experiments, which meant that the data that came out was not easy to analyze, and it needed time and effort for us to make sense of it. LDRD gave us that time and the resources to really dig into the data and take risks. For me personally, this completely changed the trajectory of my career because I come from a computational background, and now I'm a full experimental physicist.”

—Saransh Soderlind, PI



“

This started out as a feasibility study, and then we successfully developed a design and built hardware, and our proposed experiment to fly in the International Space Station was accepted. If we hadn't had the LDRD funding, this would never have happened. So, the instrument would never have flown at all.

—Matthew Horsley, PI

”

LLNL's prototype telescope is now fully operational aboard the International Space Station

When SpaceX's Dragon spacecraft docked with the International Space Station (ISS) on March 16, 2025, it delivered several thousand pounds of supplies for the crew as well as new hardware. The hardware included the U.S. Space Force's Space Test Program Houston 9 (STP-H9) platform, which houses a prototype telescope designed and built by LLNL's Space Science and Security Program.

The Stellar Occultation Hypertemporal Imaging Payload (SOHIP) prototype telescope uses LLNL-patented monolithic-optics technology on a gimbal to detect and characterize gravity waves and high-altitude atmospheric properties such as temperature, pressure, and air density profiles at altitudes of up to 50 kilometers (or about 31 miles).

Now in “science mode” and fully operational aboard the ISS, Livermore's prototype telescope is measuring atmospheric properties with high resolution at unprecedented altitudes.

MISSION SUPPORT

SOHIP's continued successful operation advances our understanding of atmospheric dynamics, opening new avenues for scientific discovery and modeling in **Energy Security** and **Multi-Domain Deterrence**.

Earth and Atmospheric Sciences

Matthew Horsley
Principal Investigator



Lasers and Optical Science and Technology

LLNL leads an initiative to develop new high energy laser architectures

LLNL is leading a multifaceted program that combines high-power laser development, high-energy particle physics, plasma physics, advanced numerical simulations on high performance computing (HPC) systems, and systems engineering and integration. The goal is to demonstrate the capabilities of new laser materials and architectures and explore their limits.

Development and use of new laser materials enables smaller, lighter, cheaper, and more portable lasers for a multitude of applications in high energy density science, material characterization, surface modification, imaging, and production of secondary sources of particles and radiation.

MISSION SUPPORT

Exploring the potential of new laser materials enables breakthroughs and revolutionary advances in laser-driven capabilities for **Energy Security**, **Multi-Domain Deterrence**, and **Strategic Deterrence**.



Tom Spinka
Principal Investigator



Photo courtesy of LLNL.

“

The LDRD program's acceptance of high-risk, high-reward research enabled me to pursue a 'crazy idea' that has blossomed into a whole research ecosystem within the NIF&PS directorate with world-leading results targeting multiple new application areas of interest to LLNL's missions.

—Tom Spinka, PI

”



“

The support from LDRD gave us the flexibility and resources to develop and carry out the innovative measurement approaches needed to address the gallium anomaly. Without LDRD, we simply wouldn't have been able to delve so deeply into this issue and, therefore, wouldn't have been able to provide important new insights in neutrino physics.

—Nicholas Scielzo, PI

”

New measurements confirm Germanium isotope half-life

The stable nucleus ^{71}Ga is used as the detector material in several neutrino experiments because neutrino interactions can transform it into ^{71}Ge , a radioactive isotope with an 11-day half-life that can then be observed with traditional radiation detectors. However, the rate of ^{71}Ge production is far short of expectations, giving rise to what is referred to as “the gallium anomaly.” This anomaly cannot be explained by current theories and has given rise to speculation about new, unexpected neutrino properties, such as the ability to transform into other exotic particles. Recently, a suggestion was made that this anomaly could be explained by something simpler: a mismeasurement of the half-life for the ^{71}Ge nucleus.

To test this possible explanation of the gallium anomaly, a team of scientists from LLNL and the Lawrence Berkeley National Laboratory performed a set of careful measurements that determined the ^{71}Ge half-life with about four times greater precision than any previous measurement. The new half-life obtained by the team confirmed the previous half-life value, putting it on much firmer footing and definitively ruled out the possible explanation of an incorrect ^{71}Ge half-life.

MISSION SUPPORT

By deepening our understanding of fundamental nuclear processes, these findings enhance the precision and reliability of technologies that underpin national security and **Strategic Deterrence**.

Nuclear, Chemical, and Isotopic Science and Technology

Nicholas Scielzo
Principal Investigator





Keith Morrison
Principal Investigator

**Synthetic antibacterial minerals
combat topical infections**

A team of LLNL scientists has found that synthetic antibacterial minerals exhibit potent antibacterial activity against topical MRSA infections and increase the rate of wound closure.

The discovery of natural clay mineral deposits with iron-based antibacterial activity revealed geochemical reactions that maintain ferrous iron and reactive oxygen species can serve as potent antimicrobials. However, these zones in the natural deposit are too variable to make a product for clinical applications. This team developed a patentable mineral synthesis method that reproduced the antibacterial activity observed in the natural samples.

These results support the use of an “iron overload” strategy to combat antibiotic-resistant infections. A patent was accepted for this technology, with the goal of partnering with industry to commercialize this novel antibacterial approach.

MISSION SUPPORT

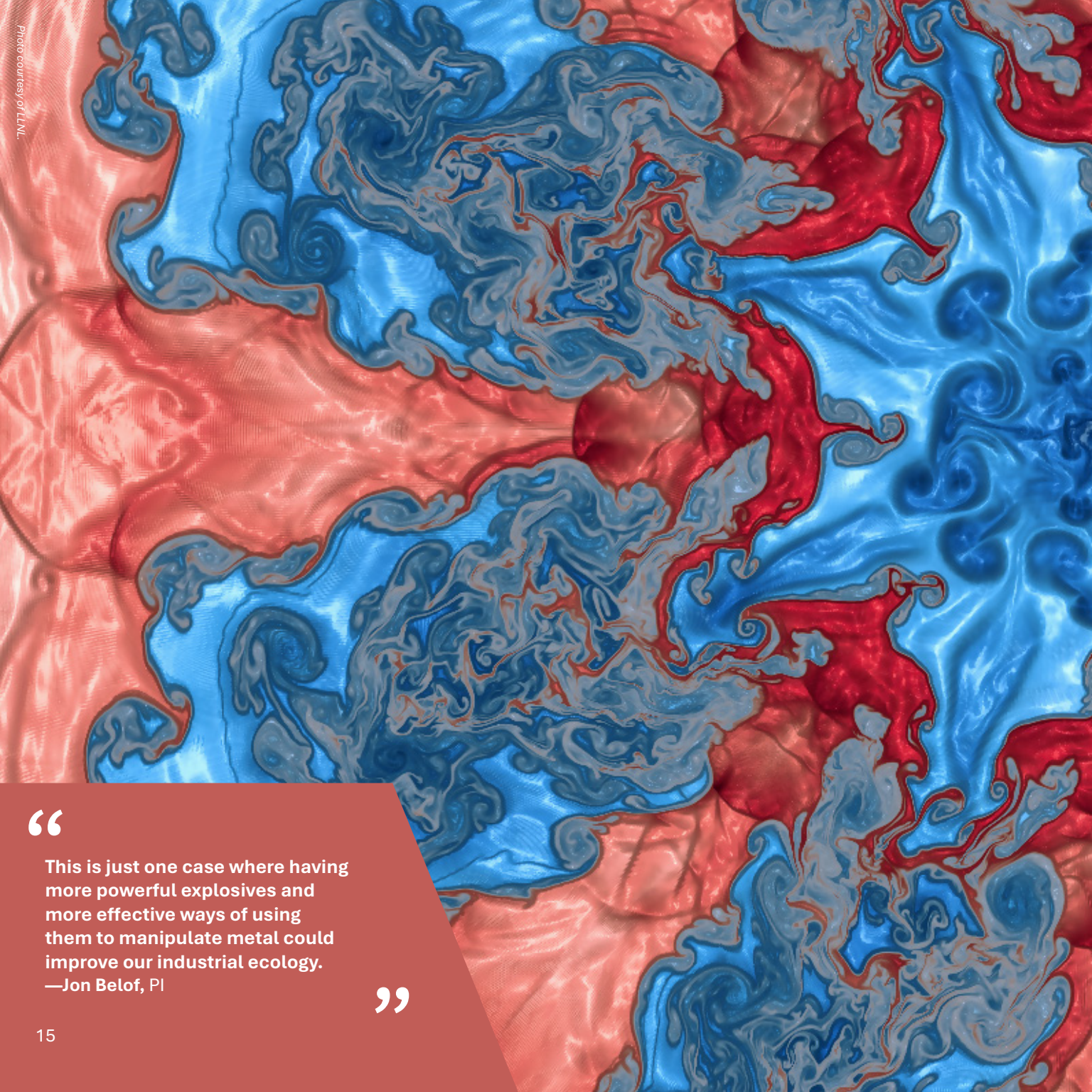
In the age of antibiotic resistance, synthetic antibacterial minerals offer new strategies for combating infections, supporting advancements in **Threat Preparedness and Response.**

Photo courtesy of LLNL.



“LDRD funding was vital because it was high-risk, high-reward at the early stages. We had found these natural minerals that could kill every known antibiotic resistance strain of bacteria. However, the natural minerals were too variable to make into a product for personal or clinical use. And so the idea was to synthesize them and then make synthetic versions with controlled and tunable reactivity that could be patented and be made into actual product.
—Keith Morrison, PI

”



“

This is just one case where having more powerful explosives and more effective ways of using them to manipulate metal could improve our industrial ecology.
—Jon Belof, PI

”

Special pairs of shocks and phase transitions suppress Richtmyer-Meshkov instability

A team at LLNL has explored new frontiers of hydrodynamics research by showing that specific sequences of shockwaves can effectively manage Richtmyer-Meshkov instability (RMI). RMI is a phenomenon commonly observed in fluid dynamics when different densities of materials interact under shockwave conditions.

The control of Richtmyer-Meshkov instability has profound implications across multiple scientific fields, including inertial confinement fusion, astrophysics, materials science, and energy research. This discovery may open new avenues for research in controlling high-velocity impacts and explosions, potentially leading to advancements in protective materials design and energy harnessing methods.

MISSION SUPPORT

By relying on supercomputing resources and multiphysics simulation codes, this hydrodynamics modeling drives important progress in **mission-related** applications.



Stockpile and Enterprise Transformation

Jon Belof
Principal Investigator



Computational solutions push the boundaries of brain-on-a-chip technology

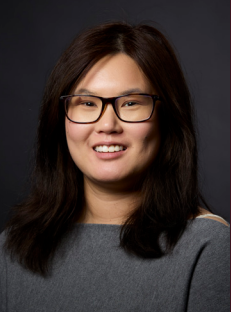
Brain-on-a-chip (BOC) systems are engineered cell-culture models that allow non-invasive, real-time monitoring of electrochemical processes. However, the ability to monitor the functional dynamics of the entire 3D reconstructed neural tissue remains a major bottleneck.

For the first time, an LLNL team has developed a computational pipeline that can be implemented to better interpret network activity within an engineered 3D neural tissue and better understand the modeled organ tissue.

This research shows that combining the high spatial resolution of 3D multi-electrode arrays with sensitive computational tools can track and quantify changes in synchronicity within subpopulations of neural networks—both within and between cross sections. It can also distinguish networks that are sensitive or insensitive to chemicals, as well as those that become inactive as a result of chemical exposures.

MISSION SUPPORT

Through the rapid and precise assessment of neural tissue responses, this breakthrough advances capabilities for **Threat Preparedness and Response**.



Doris Lam
Principal Investigator

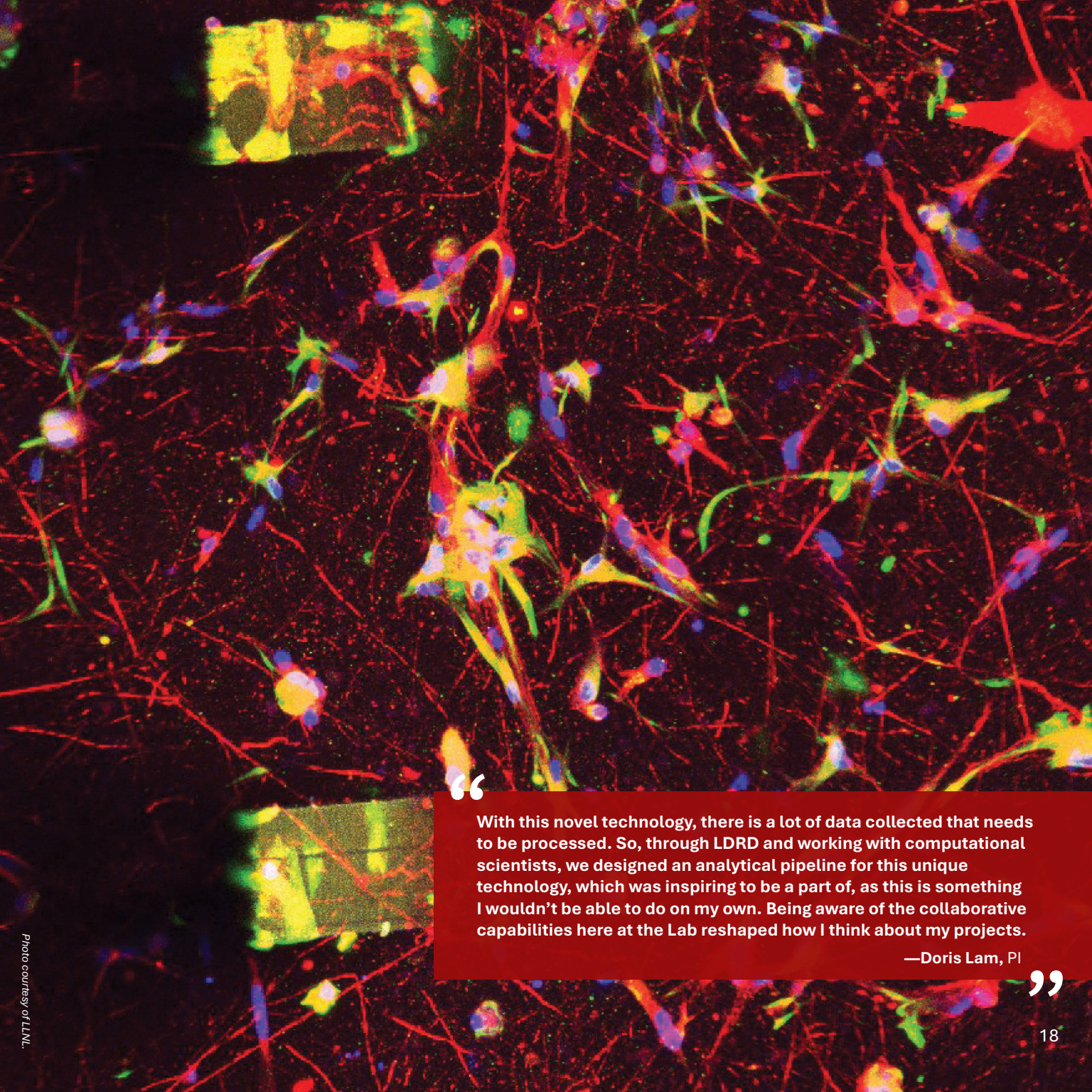
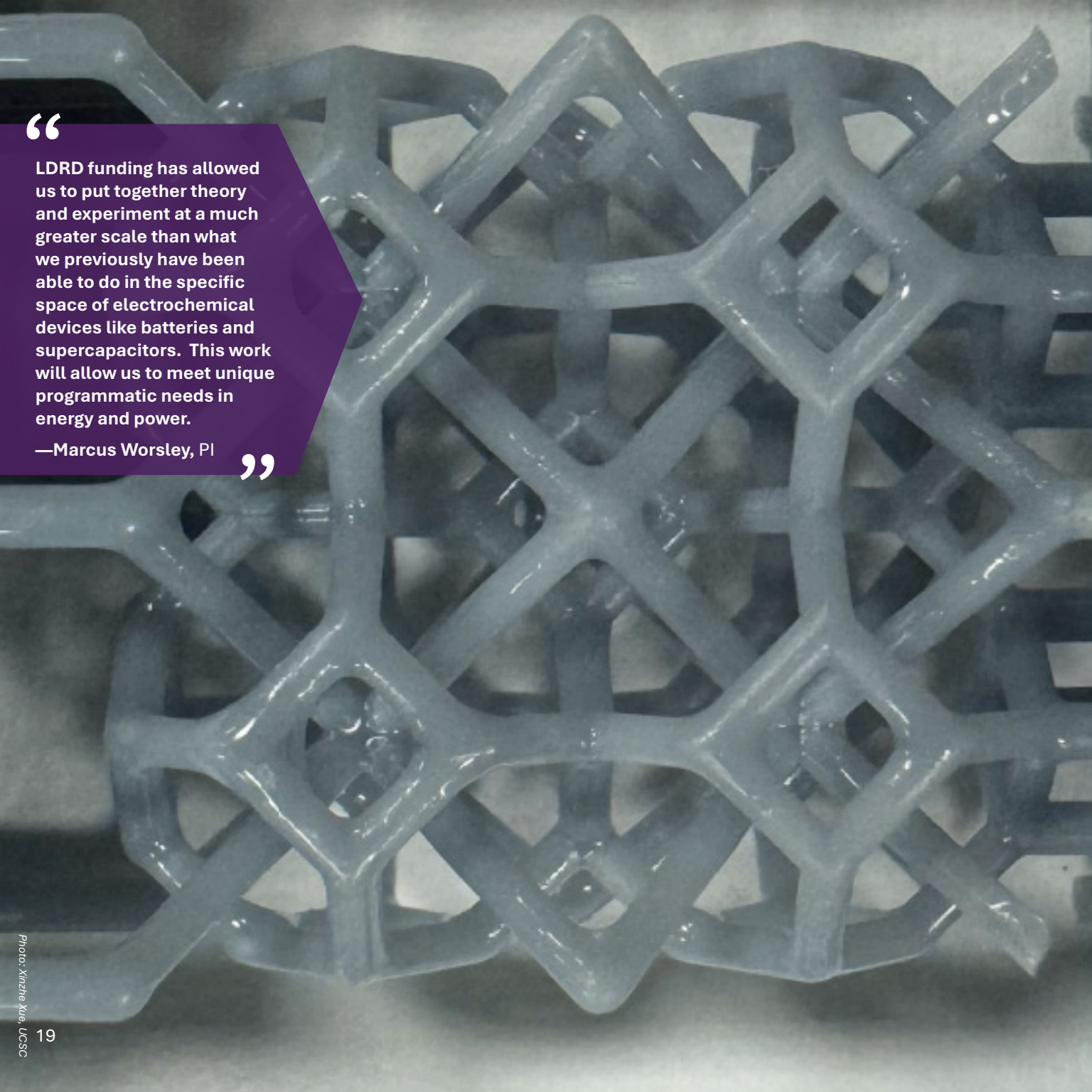


Photo courtesy of LLNL.

“With this novel technology, there is a lot of data collected that needs to be processed. So, through LDRD and working with computational scientists, we designed an analytical pipeline for this unique technology, which was inspiring to be a part of, as this is something I wouldn’t be able to do on my own. Being aware of the collaborative capabilities here at the Lab reshaped how I think about my projects.”
—Doris Lam, PI



“

LDRD funding has allowed us to put together theory and experiment at a much greater scale than what we previously have been able to do in the specific space of electrochemical devices like batteries and supercapacitors. This work will allow us to meet unique programmatic needs in energy and power.

—Marcus Worsley, PI

”

3D-printed electrodes boost performance of next-gen energy storage devices

The architectural design of electrodes offers new opportunities for next-generation electrochemical energy storage devices (EESDs) to increase storage capacity and performance. Conventional approaches to increase storage capacity via thick electrodes decrease performance due to increased ion diffusion length and larger ion-concentration gradients, which limit device kinetics.

To overcome these challenges, LLNL scientists and collaborators at the University of California, Santa Cruz 3D-printed a new and compact device configuration with two interpenetrated, individually addressable electrodes, allowing precise control over the geometric features and interactions between the electrodes.

MISSION SUPPORT

By enabling high-performance energy storage in various conditions, these new designs and materials strengthen the foundations of reliable and resilient **Energy Security.**

Earth System Resilience

Marcus Worsley
Principal Investigator



Strategic Advantage

LLNL partners to deploy monolithic telescopes

Starris and LLNL have entered a commercialization partnership for LLNL’s patented monolithic telescope technology, which accelerates rapid deployment of modular optical designs for high-resolution or high-sensitivity space imagery.

Through partnerships like these, industry will commercialize and scale the LLNL monolithic telescope technology particularly for the detection, tracking, cataloging, and identification of artificial objects, including satellites, spent rocket bodies, asteroids, or debris. In parallel, monolithic telescopes advance astrophysical research through time-domain astronomy, capturing transient phenomena. The compact yet robust monolith enables tactically responsive space, with the ability to deliver on-orbit capabilities with speed and agility.

MISSION SUPPORT

The deployment of these proliferated optical sensor networks enhances space domain awareness and scientific discovery, strengthening national security through **Multi-Domain Deterrence**.



Frank Ravizza
Principal Investigator



Photo courtesy of LLNL.

“

LDRD enabled the critical foundational R&D for our monolithic space telescope technology and laid the groundwork for sponsor-funded maturation efforts that culminated in a flight mission with Anduril. This technology now supports nationally critical space missions and drives commercialization opportunities for our industry partners. None of this would have been possible without LDRD.

—Frank Ravizza, PI

”

LLNL LDRD METRICS BY THE NUMBERS FY24

LLNL’s most significant resource for supporting internally directed high-risk/ high-payoff research and development, providing investments in cutting-edge science, technology, and engineering to advance our mission goals.



6%
of LLNL’s costs funds the
LLNL’s LDRD program.

\$180M
LDRD Budget



409 peer-reviewed
publications produced



234 Postdoctoral
Fellows supported



216
Students supported

126 patents supported



31% of LDRD projects included
funded collaborations with
university and industrial partners



43% of R&D 100 Awards have LDRD roots



For more information on the highlighted projects, visit the LDRD Annual Report:
<https://ldrd-annual.llnl.gov>

OR SCAN HERE

