Also in this issue:
Laboratory Operations in a Pandemic
Energetic Materials Center Anniversary
Disruptive Research Results
At Lawrence Livermore National Laboratory, we focus on science and technology research to ensure our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. Science & Technology Review is published eight times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

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About the Cover

As described in the multi-part feature beginning on p. 4, Lawrence Livermore National Laboratory’s research expertise in astrophysics, nuclear science, cosmochemistry, and data science is uniquely tuned to answer questions about the past and future of our solar system. This month’s cover illustration represents planets, moons, and other heavenly bodies, on a large scale, which researchers explore on a much smaller scale, including examination of biomolecules sparked by asteroid bombardments and isotopic differences among extraterrestrial samples.

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Finding Sterile Neutrinos

The existence of theoretical particles called “sterile neutrinos” could offer a deeper understanding of dark matter, the strange material that permeates the universe and accounts for 85 percent of its total mass. Livermore scientist Stephan Friedrich led a team from Lawrence Livermore National Laboratory and the Colorado School of Mines in an experiment funded by the Laboratory Directed Research and Development (LDRD) Program demonstrating the power of using nuclear decay in high-rate quantum sensors in the search for sterile neutrinos. The findings are the first measurements of their kind and appeared in the January 13, 2021, issue of Physical Review Letters. In the experiment, nicknamed the “BeEST” (Beryllium Electron-capture with Superconducting Tunnel junctions), researchers implanted radioactive beryllium-7 atoms into superconducting sensors developed at Livermore. A process called electron capture—in which an electron in an atom’s inner shell is drawn into the nucleus and combines with a proton—decayed the beryllium-7, forming lithium-7 and a neutrino. The neutrino then escaped, making it undetectable, but the reduced recoil energy or byproduct of the lithium-7 produced a measurable signal of the neutrino mass.

The team performed simulations on Laboratory supercomputers to gain confidence in the detection of sterile neutrinos and understand the materials effects in the detector. Friedrich says, “This research lays the groundwork for more intensive studies for these new particles using large arrays of sensors with newsuperconducting materials.” Contact: Stephan Friedrich (925) 423-1527 (friedrich@llnl.gov).

Doubling Laser-Produced Antimatter

The ability to create numerous positrons in a laboratory setting opens new doors to antimatter research, including the understanding of physics underlying astrophysical phenomena such as black-hole accretion and gamma-ray bursts. Livermore physicists used the high-intensity OMEGA Extended Performance (EP) laser at the University of Rochester’s Laboratory for Laser Energetics to shoot through a gold target. A team of scientists has developed and tested a deep-learning initial projects are discussed in the highlight beginning on p. 20. A team of scientists has developed and tested a deep-learning algorithm to derive a small model—a mathematical equation—from larger models to make predictions. A second project aims to develop methods for performing complex nuclear calculations on a prototype quantum computer. Yet another team is striving to significantly increase laser power and intensity using plasma rather than solid optics as the amplifying medium. All these remarkable projects are being carried out under COVID-19 pandemic conditions. A third highlight (p. 12) in this issue of S&T&R discusses how we are enforcing a top priority, protecting employees’ health, while pursuing “Science and Technology on a Mission” at Lawrence Livermore National Laboratory.

Looking to the Past and the Future

Three decades of innovation at the Laboratory’s Energetic Materials Center (EMC) are celebrated in the highlights beginning on p. 16. EMC scientists provide critical expertise and cutting-edge research in support of the national deterrent and keeping the nation safe from emerging explosives and nuclear proliferation. As the country’s leading repository of energetic-materials expertise, EMC has been responsible for many landmark S&T developments and faces significant future challenges supporting the nation’s strategic modernization program. The Laboratory leads the charge to develop means to remanufacture an insensitive high explosive not in production since the early 1990s and has developed a novel new explosive for use in stockpile modernization.

We look to address future national needs and explore S&T possibilities through the Department of Energy’s Laboratory Directed Research and Development (LDRD) Program. At the Laboratory, we created a Disruptive Research projects that are discussed in the highlight beginning on p. 20. A team of scientists has developed and tested a deep-learning algorithm to derive a small model—a mathematical equation—from larger models to make predictions. A second project aims to develop methods for performing complex nuclear calculations on a prototype quantum computer. Yet another team is striving to significantly increase laser power and intensity using plasma rather than solid optics as the amplifying medium. All these remarkable projects are being carried out under COVID-19 pandemic conditions. A third highlight (p. 12) in this issue of S&T&R discusses how we are enforcing a top priority, protecting employees’ health, while pursuing “Science and Technology on a Mission” at Lawrence Livermore National Laboratory.

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**SHOCKING START TO LIFE**

**EARTH** coalesced from a protoplanetary disk of gas, dust, and aggregations of particles about 4.5 billion years ago. Primordial Earth was a hostile place—volcanism, extreme heat, a turbulent atmosphere, intense ultraviolet radiation from a young, hot sun, and continual bombardment from comets and meteorites. How could such unwelcome conditions lead to a prebiotic chemistry that gave way to proteins, lipids, and other biomolecules between 3.5 and 4 billion years ago? Researchers at Lawrence Livermore are exploring an unexpected pathway to the organic precursors of early biomolecules—precursors that originate with the impacts of astrophysical bodies on Earth. Comets, made mostly of water, ice, and dust, have been known since the 1970s to also contain a number of small molecules such as ammonia (NH₃) and methanol (CH₃OH). In 2009, Comet Wild II (pronounced “vilt 2”) was found to contain glycine, the simplest protein-building amino acid. The impact of comets provides abundant energy to drive chemical reactions that could produce a wide array of organic chemicals that are the building blocks of biomolecules.

Nir Goldman, a computational chemist and deputy group leader of the Non-Equilibrium Theory Group in the Laboratory’s Materials Science Division, leads research that uses Livermore’s high-performance computing (HPC) capabilities to simulate the chemistry that takes place when comets or other icy materials bearing organic chemicals collide with Earth. Goldman and his team build on an earlier study, funded by Livermore’s Laboratory Directed Research and Development (LDRD) Program, of shock-compressed materials to determine whether prebiotic compounds such as amino acids might emerge under high temperatures and pressures.

“Experiments to recreate such conditions are extremely challenging due to the large number of interconnected variables at play,” says Goldman. “Factors include the composition of the material to be studied and the peak conditions achieved during shock compression. Analyzing the products after the shock process is one of the biggest challenges. A plethora of reactions can take place, and contamination from biological sources—for example, a researcher’s hands—is extremely easy.”

Simulating Shock

To help direct experimental shock compression efforts, Goldman and his colleagues performed quantum mechanical simulations of prebiotic shock synthesis to explore what happens chemically under impact conditions of a comet. After setting up initial conditions including pressure and temperature, initial mix of chemicals, strain rates, and other parameters, the simulations modeled comet impact conditions at the atomic level while accurately describing the dynamic breaking and forming of chemical bonds. In this case, their simulations spanned more than 50 gigapascals (GPa)—nearly 50,000 times Earth’s atmospheric pressure—and temperatures up to 5,000 kelvin. “The real art of these simulations is the judicious choice of setting these boundary conditions in a simulation designed to show the effects of comet-impact conditions,” says staff scientist and computational chemist Matthew Kroonblawd, a member of Goldman’s team.

“In the simulation, we were able to model the conditions in the post-shock ice mixture,” says Kroonblawd. “We studied the time evolution of the shock wave, comparing the macroscopic properties such as pressure and temperature with the microscopic properties such as density and velocity of the molecules.”

To their surprise, simple mixtures of water, small organic compounds, and ammonia yielded amino acids and a number of other potentially life-building compounds when subjected to these intense conditions. Later, confirming experiments were performed using a high gas-gun facility at the University of Kent. An aqueous mixture of similar composition was subjected to an impact shock of more than 50 GPa, and researchers identified a large variety of amino acids in the post-shock ice mixture.

“A follow-up study in 2019 by Kroonblawd, Goldman, and Livermore’s Rebecca Lindsey reported the results of simulating a mix of glycine and water under impact scenarios including cooling and equilibrating to ambient conditions. In this case, carbon-rich structures condensed under high pressures and temperatures and subsequently unfolded into nitrogen-containing polycyclic aromatic hydrocarbons (NPAHs) during fracture and cooling. NPAHs are important prebiotic precursors for synthesizing molecules that are the basis of complex proteins such as RNA and DNA.”

Path to Prebiotic Compounds

Research published in 2020 by Brad Steele, Goldman, I-Feng “Will” Kuo, and Kroonblawd simulated a rotational diamond anvil cell experiment. Rotating diamond anvils apply a compressive shearing force to a small chamber containing a glycine mixture. A modeled compressive shear stress of 10 GPa produced a complex chemistry of prebiotic compounds including polypeptides, such as chains of amino acids that form the building blocks of proteins. These studies indicate that simple molecules like glycine support richly varied chemistry under extreme conditions when complex molecules are formed.

Researchers at Lawrence Livermore are also exploring an unexpected pathway to the organic precursors of early biomolecules—precursors that originate from the atomic level to the building blocks of proteins such as RNA and DNA.

**EXPLORING OUR PAST AND FUTURE**

How could life begin from a swirling chaos? How did Earth and its moon form? What can lunar rocks from the Apollo missions reveal? And what will scientists learn from exploration on distant moons? These questions are addressed in this four-part feature article on Lawrence Livermore’s space science research.

**S&TR August 2021**
Creating Timetables

The most exciting element of cosmochemistry research, according to Brennecka, is learning how every facet links together. “Through examining a variety of samples, we can build a picture of not only how the planets form and evolve, but how the solar system came into being,” he says. The Laboratory enables this groundbreaking cosmochemistry work by having the best analytical capabilities and equipment to measure isotopic ratios. “I can’t think of any other place that has such an assortment of capabilities under one roof.”

With a team comprised of Livermore’s Laboratory Directed Research and Development (LDRD) Program, Bloomberg and Brennecka position isotopic signatures of neon, deuterium, and chlorine in samples of terrestrial planets, and other cosmic phenomena. “Livermore has a seat at the table when the academy assesses key scientific questions in planetary science and astrobiology — some missions and initiatives for the decade 2023–2032,” says Borg. Other sample-collection missions include the Mars Sample Return Campaign, scheduled to launch in 2026, and the OSIRIS-REx mission, set to return asteroid samples in 2023. In addition, large quantities of lunar samples from many new areas of the Moon are expected to be returned when NASA’s ARTEMIS manned space flight program takes shape in the future. “We have become a one-stop shop for extraterrestrial geochronological analysis and there are some fantastic sample-analysis opportunities ahead,” says Borg. “It’s an exciting time to be in the field and at Lawrence Livermore.”

A Storied History of Isotopic Analysis

The Laboratory has long been in the business of studying isotopes. Early on, its cosmochemists conducted isotopic analyses for atmospheric and underground nuclear tests; today, nuclear forensics plays a key role in the Laboratory’s security missions. (See S&TR, April/May 2018, pp. 4–11 and S&TR, October/November 2014, pp. 12–18.) Livermore’s Lars Borg sees only a short step from applying isotopic research to nuclear forensics to answering questions of cosmochronology importance. “Planetary materials undergo processes that are relevant to nuclear forensics, such as nuclear decay, neutron capture, and spallation,” he says. “Additionally, the elements of interest to cosmochemistry have multiple isotopes of interest for forensic purposes. Finally, the analytical techniques are essentially identical for both applications.”

Borg also points out that the magnitude of isotopic effects can be much more muted in natural samples, requiring precision measurements to identify extremely small isotopic differences between samples of very little mass. In many cases, the procedures the Laboratory develops for cosmochronological questions, such as determining the nucleosynthetic sources for the elements in a meteorite sample, can also be used in nuclear forensics and other mission-critical work.

Lars Borg (left) and Greg Brennecka prepare lunar samples for isotopic measurement to study the chronology of the Moon. (Photo by Garry McLeod.)

In more recent projects, including Borg’s work with Livermore’s Thomas Knutson, Josh Wimpenny, and Cortlin Sio, researchers have turned to isotopic analysis to pin down when Mars’ “magma ocean” began to solidify into the planet’s mantle. Thermal models predicted this solidification would have started less than 1 million years after the formation of the planet’s core. To test this, the team applied the 1972, during the last Apollo mission. Livermore’s cosmochemists also serve with a team analyzing recently opened core samples gathered on the Moon in 1972, during the last Apollo mission. This work is focused on chronology of previously unexamined samples and serves to gather information on the behavior of volatile elements on the Moon and Earth.

Borg, who has been named to the National Academy of Science’s Planetary Science and Astrobiology Decadal Survey steering committee, notes that this research effort positions the Laboratory for conducting forensic analyses of samples from future Moon missions. “Livermore has a seat at the table when the academy assesses key scientific questions in planetary science and astrobiology — some missions and initiatives for the decade 2023–2032,” says Borg. Other sample-collection missions include the Mars Sample Return Campaign, scheduled to launch in 2026, and the OSIRIS-REx mission, set to return asteroid samples in 2023. In addition, large quantities of lunar samples from many new areas of the Moon are expected to be returned when NASA’s ARTEMIS manned space flight program takes shape in the future. “We have become a one-stop shop for extraterrestrial geochronological analysis and there are some fantastic sample-analysis opportunities ahead,” says Borg. “It’s an exciting time to be in the field and at Lawrence Livermore.”

Key Words: Allende meteorite, Apollo mission, astrophysics, cosmochronology, Giant Impact, isotopic analysis, isotopic signature, Laboratory Directed Research and Development (LDRD) Program, Moon, Mars, meteorite, NASA, solar system.

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GAMMA RAY EYES ON DISTANT MoONS

GAMMA RAYS—high-energy electromagnetic waves produced by the decay of radioactive isotopes—are found in the depths of space and on the surface of planets, planetoids, and moons. In space, neutron stars, pulsars, and supernova explosions emit gamma rays. On planets, cosmic ray bombardment and the less dramatic process of radioactive decay produce gamma rays. Lightning and nuclear explosions on Earth yield them as well. Since gamma-ray emission provides a unique fingerprint of a radioactive material’s isotopic composition, the Laboratory has long been in the business of designing and fielding gamma-ray spectrometers. Used in national security, the devices locate radioactive materials at shipping ports and border crossings. As nuclear safeguards, they identify and quantify the isotopes in nuclear processing facilities.

Lawrence Livermore is also recognized for its development of germanium-based gamma-ray spectrometers for planetary exploration. The high-purity germanium crystals in these detectors provide excellent resolution at ~180°C, a requirement that presents its own challenges when journeys take years and temperatures are extreme. Germanium-based gamma-ray detector developed by Livermore’s Morgan Burks, Geon-Bo Kim, and Nathan Hines will be part of deep-space missions to the asteroid Psyche-16 (launch date 2023), the two moons of Mars (2024), and Saturn’s moon Titan (2027). The Livermore team collaborates with Johns Hopkins University Applied Physics Laboratory (APL) researchers, who integrate the gamma-ray detectors with other instrumentation and deliver the final systems to NASA.

An Established Collaboration

This effort isn’t the “first rodeo” for the Livermore–APL collaboration. About 20 years ago, Livermore and APL developed a lightweight, germanium-based gamma-ray spectrometer for NASA’s MESSENGER mission to Mercury (See S&TR, June 2005, p. 23–24.) The venture provided new insights, causing researchers to reconsider theories on Mercury’s formation. That instrument led to the GeMini, a germanium (Ge)-based spectrometer with a ultraminiature electromechanical cooling system (Mini). Low power, low mass, low weight, and rugged, the R&D100 Award–winning GeMini was small enough to hold in the palm of one hand. (See S&TR, October/November 2009, pp. 8–9.)

The GeMini gave way to the versatile GeMini-Plus, which sports an improved, simplified, and more rugged design. The team recently delivered the GeMini-Plus for the mission to Psyche-16, located on the asteroid belt between Mars and Jupiter. Psyche is composed largely of iron, unlike most asteroids, which are mostly rock. “Psyche is thought to be a planetary core, a remnant of a collision during the early stages of the development of the solar system,” says Burks. Data gathered by the GeMini-Plus on the elemental composition of Psyche’s surface could provide insights into the cores of our solar system’s “inner planets” of Earth, Mars, Mercury, and Venus—and into planetary evolution and formation. (See S&TR, May 2019, pp. 17–19.)

Outfitting New Instrumentation

A modified GeMini-Plus will be incorporated into NASA’s Mars-Moon Exploration with Gamma rays and Neutrons (MEGANE) instrument, which will use gamma-ray and neutron spectroscopy to measure the elemental composition of the two Mars moons, Phobos and Deimos. MEGANE is one of eleven instruments slated for the Japan Aerospace Exploration Agency’s Martian Moons Explorer (MMX). “Our spectrometer may help answer some fundamental questions about how Mars’s moons were formed,” says Burks. “Are they captured asteroids? Remnants of a big impact on Mars? Or, accreted leftover material from Mars’s formation? We hope to find out.” After conducting remote-sensing measurements of both moons, the MMX will land on the surface of Phobos, grab a sample of its moon dust, and fly back to Earth. The round-trip mission is expected to take about five years.

While engineering the spectrometer for MEGANE/MMX, the team is also hard at work on the instrument for the Dragonfly mission. Part of NASA’s New Frontiers program, Dragonfly will search for the building blocks of life on Saturn’s largest moon, Titan. The eight-bladed rotorcraft will maneuver like a large drone, zooming about the icy moon’s surface, landing to take samples, and taking off again. Livermore’s gamma-ray detector will measure the elemental composition of the landing sites, helping with site characterization and sample selection. “Titan has a dense, nitrogen-based atmosphere along with methane clouds and rain,” Burks notes. “The surface has liquids, ammonia ices, and complex organic molecules, which could be precursor molecules to life.”

In addition to preparing detectors for these missions, Burks and his team are also involved in a project funded by the Laboratory Directed Research and Development Program to develop a science capability that complements the Laboratory’s space-based hardware competencies. Burks explains, “The Laboratory is now viewed as an expert in delivering gamma-ray spectroscopy instrumentation for space exploration. That expertise and our competencies in nuclear science put us in an excellent position to contribute to nuclear planetary science and aid in transferring the technology we’ve developed for space applications to the next-generation of terrestrial search instruments.”

—Ann Parker

Key Words: asteroid belt, detector, Dragonfly, gamma-ray spectrometry, GeMini-Plus, germanium (Ge)-based spectrometer, Japan Aerospace Exploration Agency, Johns Hopkins University Applied Physics Laboratory (APL), Mars-Moon Exploration with Gamma rays and Neutrons (MEGANE), Martian Moons Explorer (MMX), MESSENGER, NASA, New Frontiers program, Phobos, Psyche-16, Saturn, Titan.

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WELDING WITH ASTEROIDS?

NEWS articles and media outlets regularly buzz with opinions and progress on the future of establishing colonies in space and on the Moon and Mars. Such possibilities, once the stuff of science fiction, are now on the way to becoming science fact. These endeavors will require building and maintaining structures for transportation and habitation. For off-Earth structures, space adventurers will most likely need materials at hand for fabrication and repairs. Lawrence Livermore materials scientist John Elmer explains, “Transporting large amounts of traditional building materials such as aluminum, titanium, and stainless steel from Earth into space is expensive. Materials for space construction and repairs will most likely come from the Moon, asteroids, or meteorites.”

Asteroids—large “rocks” orbiting the Sun—and meteorites—asteroids that crash onto planets or moons—often have a high percentage of iron and nickel, two important elements of stainless steel and low expansion, Invar alloys. “People have suggested that perhaps these metal-rich objects could be used for extraterrestrial construction,” says Elmer.

Key to construction is the capability to weld. In the 1970s, experiments on NASA’s Skylab space station proved the feasibility of electron-beam welding steel in space, where conditions are ideal since the welding technique requires a vacuum to operate. However, the Skylab experiments used high-quality steel that had been refined on Earth to the proper metallurgical sense,” says Elmer. “With more innovative thought and technical elbow grease, welding in space could become a reality.”

Elmer rounded up a team, including Livermore’s Gordon Gibbs, Lenny Summers, Gil Gallegos, Cheryl Evans, and James Embree, and obtained a 722-gram specimen of the Canyon Diablo meteorite, which plunged to Earth about 50,000 years ago, shattering and forming the 1.3-kilometer-diameter Meteor Crater in Arizona. Nearly 30 tons of fragments of this iron-and-nickel-rich meteorite have been collected, making samples available for research.

Specimens were electron-beam welded at the Laboratory in a vacuum similar to the vacuum of space. The welds were several millimeters deep, typical of those needed to join parts. However, the small welds cooled much more rapidly than meteorites. “An asteroid in space can cool from its initial formation, a high voltage power supplies. “Still, it’s an intriguing proposition that makes metallurgical sense,” says Elmer. “With more innovative thought and experimentation, plus some creative, technical elbow grease, welding in space would become a reality.”

Refining Space Materials

One intriguing possibility, which Elmer described in a 2018 patent, would be to refine the asteroidal or meteoritical iron using existing elements known to be present on the Moon’s regolithic surface. The first step would be identifying an asteroid or meteorite with a high percentage of iron, mining it, and then metallurgically refining the material to remove impurities harmful to steel making and welding. Once refined, the material could be atomized into powder, facilitated by the low-gravity and vacuum of space. “This powder could be used to additively manufacture steel parts using conventional electron-beam or laser-beam 3D printing methods—welding-related processes that also require high-quality metal,” says Elmer. He adds that 3D printed parts could be welded together to create larger structures, as on Earth. In fact, the International Space Station and NASA demonstrated the feasibility of printing 3D parts in space in 2014.

Many challenges remain for doing this work using extraterrestrial iron. For instance, refining the metal requires significant amounts of energy, and electron-beam generation requires high voltage power supplies. “Still, it’s an intriguing proposition that makes metallurgical sense,” says Elmer. “With more innovative thought and experimentation, plus some creative, technical elbow grease, welding in space would become a reality.”

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As the severe acute respiratory syndrome coronavirus 2 (SARS CoV-2, the virus that causes COVID-19) spread to the United States in early 2020, Livermore reacted rapidly, initiating a Pandemic Response Team (PRT) on February 3, 2020, to activate the Laboratory’s pandemic plan. No one expected that the plan assembled in 2009 and updated every few years would be required for as long or have an operational impact as broad as the COVID-19 pandemic demanded. Since then, Livermore has worked diligently to keep employees safe while maintaining mission-critical operations to keep the nation safe.

**Priority One: Safe Operations**

Kathleen Noonan, a nurse practitioner with training in epidemiology and a shelf full of books about the 1918 Spanish Flu pandemic, stood ready to respond. As mission assurance manager for Livermore’s Health Services Department (HSD), she was notified in January 2020 regarding an employee returning from China. “He was our first at-risk patient,” says Noonan. “I met him at his Livermore home, asked him to quarantine, and provided him with a mask and cleaning supplies.” From that point, HSD clinicians consulted a list of employees traveling outside the United States and isolated those returning from China and other at-risk areas.

On March 16, 2020, officials in Alameda County, California—which includes the city of Livermore—issued a shelter-in-place order to begin at midnight. The same day, then-Laboratory Director Bill Goldstein announced that Lawrence Livermore would move into minimum safe operations, reducing onsite staff to the minimal level required to operate the site and its facilities safely and securely, and to carry out a limited number of mission-critical activities. Overnight, the Laboratory’s onsite population went from nearly 8,000 to just a few hundred. Employees who could telecommute were encouraged to do so, onsite visitors were limited, and business travel was restricted—all in an effort to prevent the virus from spreading.

Staff from the Operations and Business Principal Directorate addressed the formidable task of working through a checklist to ensure nonessential equipment and facilities were properly shutdown. The Security Organization implemented its standing plans to keep the Laboratory secure. Within a week, the shutdown was complete, leaving a skeleton crew of maintenance, facilities, and asset managers onsite to keep essential operations running.

**Transition to Telecommuting**

Shifting thousands of employees to telework placed new hardware and software demands on the Laboratory. While classified work must be conducted onsite, employees performing business functions and unclassified research working from home needed a virtual private network (VPN) to access the Laboratory’s unclassified network. “Before the pandemic, about half of the Laboratory’s population had VPN accounts,” says chief information officer Doug East.

Signing up 3,000 people for a VPN account in one week is difficult. Prior to the shelter-in-place order, Livermore’s Information and Technology (LivIT) Program had developed a simplified process to enable and create VPN accounts. LivIT dedicated many hours to add a second VPN service, more than doubling their capacity to meet the new demand. In addition, telecommuting employees required an at-home technology.
COVID-19 Operations

S&TR August 2021

COVID-19 Operations

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setup—laptop, monitor, and peripherals. Information technology organizations within each directorate and LivIT worked together to distribute computers as needed, and LivIT assisted with software and account setup.

The next challenge: addressing changes in the way telecommuting employees communicated with one another. In response, applications supporting video conferencing and collaboration such as WebEx, Microsoft Teams, and Jabber were expanded to serve all telecommuters. By late March, most Laboratory employees were teleworking effectively. “Everyone came together, and as a result of our efforts, telecommuting has proved to be a successful and viable form of work, opening the eyes of a lot of managers,” says East. Other innovations included the implementation of cloud-based cyber protections for Laboratory email and networks and remote updates of software used at the National Ignition Facility (NIF). A secure, online platform to facilitate document review—replacing hard copy review—also came online quickly to keep projects running smoothly.

Planning for Onsite Returns

Just as quickly as the Laboratory moved into minimum safe operations, PRT and senior management began planning for a return to normal operations. Associate Deputy Director for Operations Sandra Brereton managed the Laboratory’s operational response to COVID-19. In that role, Brereton coordinated steps to safely restart mission-critical activities with the National Nuclear Security Administration. She partnered with HSD, the Biosafety Office, and the Environment Safety and Health Directorate to ensure safe onsite return.

Fully masked and maintaining social distancing, groups of managers and biosafety specialists, including Biosafety Office Leader Carolyn Hall, toured essential laboratory facilities to begin calculating how many people could work together in each setting given COVID-19 concerns, assuming everyone was properly masked. Next, the Laboratory adapted its facilities-planning software to determine the appropriate density of employees in shared spaces and to develop a customized plan for every work environment. With the help of the Laboratory’s Emergency Operations Center and the Procurement Department, each department was equipped with personal protective equipment, such as masks and hand sanitizer.

Hall led the effort to create a COVID-19 hotline running 24 hours a day, 7 days a week, which enabled any employee exposed to COVID-19 or infected by the virus to call the Laboratory for help. “From the early days of the pandemic, our priority was keeping people safe,” says Brereton. “We were surrounded by uncertainty, asking ourselves ‘How can we ensure physical and mental well-being of the staff and help them navigate the pandemic’s challenges?’” HSD created a COVID-19 case-management team, providing counseling for employees with COVID-19 and implementing additional steps to prevent onsite coronavirus transmission. Employees confirmed to have COVID-19 (or unconfirmed but experiencing COVID-19 symptoms) were required to remain offsite until cleared by HSD to return to work, as were employees exposed to confirmed COVID-19 cases and those who had traveled or attended large social gatherings.

The COVID-19 team recruited and trained employee volunteers to handle contact tracing for employees who reported a positive diagnosis either while working at the Laboratory or within a short time after leaving the site. Livermore developed a database to track COVID-19 cases, providing data on positive cases among Laboratory employees and helpful resources on Laboratory procedures, telecommuting, and coping with COVID-19 at home. For cases confirmed among Laboratory employees, contact tracing suggested that less than a dozen cases may have been attributed to onsite transmission. For those incidences, the team reviewed steps to reduce the likelihood of similar conditions that could lead to reoccurrence.

Resuming Mission-Critical Work

A core group continued working onsite throughout Minimum Safe Operations to ensure essential nuclear facilities remained safe and operable and that activities essential to the nation’s security such as weapon modernization programs and the stockpile review process were uninterrupted. As early as March 2020, the Weapons and Complex Integration (WCI) Principal Directorate initiated planning for the return of other key personnel. Phil Pellette, WCI’s associate deputy director for operations, led the Directorate’s COVID-19 planning efforts. He joined HSD and Biosafety Office staff for walkthroughs of critical facilities, developing a checklist of procedures to bring staff back to each area. Pellette met with other directorate leaders via WebEx to support their return-to-site planning.

“One of the biggest challenges we faced was meshing together different restart procedures and operational methods, as every principal associate director and associate director has unique considerations when managing their facilities,” he says.

Cindy Atkins-Duffin, the principal deputy associate director for the Global Security Principal Directorate, adds, “Balancing mission priority with safety under pandemic constraints was the biggest challenge at hand. Global Security maintains facilities required by the federal government to be available at all times, such as the National Atmospheric Release Advisory Center and the Forensic Science Center.” Lydia Camara, deputy principal associate director for operations in NIF and Photon Science Principal Directorate, adds, “One of our biggest operational challenges was communication. We wanted to give everyone up-to-date and accurate information, and we had to learn to navigate virtual communication methods and outlets together.”

Between April and June 2020, most of the essential facilities returned to operational status. By mid-July 2020, the Laboratory entered “normal operations with maximum telecommuting,” and an average of 3,500 to 4,000 people worked onsite every week. While the Laboratory opened to more staff, HSD and Biosafety experts continued monitoring COVID-19 data. An emphasis on safety and public-health protocols, such as wearing masks and social distancing, kept the virus under control at the Laboratory.

Expanding Health Services

In April 2020, as the demand for COVID-19 testing increased and community testing options remained backlogged, Biosciences and Biotechnology Division’s Thomas Bunt began exploring onsite testing options. Rapid, onsite testing capabilities would enable HSD case managers to make faster, more informed decisions about safeguarding employees. Bunt’s team acquired the equipment and reagents to perform real-time polymerase chain reaction (RT-PCR) SARS-CoV-2 tests, which had been authorized by the Food and Drug Administration during the pandemic. To meet the state of California’s legal requirements for administering the SARS-CoV-2 tests, the team applied for a Clinical and Public Health Laboratory License, registered as a Clinical Laboratory Improvement Amendments (CLIA) “high complexity testing” laboratory, and hired clinical laboratory scientists and a qualified CLIA laboratory director.

After receiving the California Department of Public Health certification, Bunt and others worked with HSD to establish and pilot an end-to-end process of patient scheduling, testing, laboratory analysis, and data reporting. On December 5, 2020, the Laboratory began onsite testing up to 20 tests a day, usually with same-day results. Over the following months the team ramped up to 100 tests per day. In January 2021, the Laboratory received authorization to provide onsite COVID-19 vaccinations to employees (federal employees and federal contractors) when vaccine supplies became available. As of the end of August 2021, HSD had dispensed well over 4,000 shots of the Pfizer vaccine. Vaccinations ramped up again in fall 2021 as the Laboratory supported its remaining unvaccinated employees in advance of a mandate requiring vaccination of federal employees and contractors.

The Laboratory’s Site Occupational Medical Director for the Laboratory, Patrick Keller, points to expanded services addressing unique needs during the pandemic. For example, HSD’s WorkingWell program titled “Health Talks” engages employees in virtual seminars and information sessions, providing updated information and findings on the virus, transition, and treatments. In time, the Laboratory reintegrated health-related activities that had been deferred in the earlier days of the pandemic such as bearing tests, in-person clinical visits, random drug testing, and assurance-testing protocols, among other services. The Laboratory continues to maintain its COVID-19 operations and carry out its national security missions while minimizing risks to employees. Leaders credit the unified, laboratory-wide effort for such an effective response. “Livermore has exemplified an incredible amount of teamwork,” says Atkins-Duffin. “The entire Laboratory has come together and persevered through all the uncertainty and changes that COVID-19 brought about.”

Key Words: COVID-19, Health Services Department (HSD), Livermore’s Information and Technology (LivIT) Program, minimum safe operations, Pandemic Response Team (PRT), severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), telecommuting, virtual private network (VPN).

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Research Highlights

THREE DECADES OF EXPLOSIVE INNOVATION

Since Lawrence Livermore’s inception in 1952, Laboratory researchers have been among the nation’s leaders in understanding, synthesizing, formulating, testing, assessing, and modeling the initiation systems and energetic materials (EM) that play an integral role in the U.S. nuclear deterrent, conventional munitions, and homeland security. The Laboratory’s Energetic Materials Center (EMC), founded in 1991, continues to build upon that critical expertise, enabling scientific investigation in support of the nuclear deterrent and keeping the nation safe from emerging explosives and nuclear proliferation.

EMs—explosives, propellants, and pyrotechnics—store energy and release it precisely as needed, making them foundational to many Laboratory programs. This family of substances can morph from solid to gas nearly instantly, reaching temperatures of thousands of degrees Celsius, and move matter several miles per second. EMs can morph from solid to gas nearly instantly, reaching temperatures of thousands of degrees Celsius, and move matter several miles per second.

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Energetic Materials Center

**High-Explosives (HE) Modeling**

Lawrence Livermore created the thermochemical modeling codes Ruby, Tiger, CHEQ, and Cheetah. Cheetah is the first, and only, code that is widely distributed, used, and validated both as a stand-alone capability and coupled with a hydrodynamic code. Cheetah simulates detonations, predicting the effects of different chemical reactants; tracking reactions at the molecular level to obtain velocity and energy; and, using this data, designing optimized explosives with custom characteristics. In 2021, the Cheetah team enabled the code to operate on graphics processing unit-based accelerators.

**New Materials**

Livermore introduced insensitive high explosives to enter the stockpile without safety testing. The Laboratory's High Explosives Response to Mechanical Stimulation (HERMES), developed in Livermore's ALE3D simulation platform, is the first model to predict a range of post-ignition responses, as pictured above.

**Advanced Manufacturing**

Livermore has always been an early-adopter of advanced manufacturing techniques including injection-molding for high-power, high-precision applications, and the first-ever use of microrreactor synthesis in the demonstration of continuous process syntheses. The Laboratory has pioneered the use of direct ink writing (DIW) for complex, multimaterial, explosive components, and recently printed the first-ever kilogram-scale additively manufactured explosive and detonated it in the High Explosives Applications Facility. The resulting additively manufactured explosive test articles (above) were part of a proof-of-concept study. The image shows the test articles, with either one or two triangular regions of a “fast” detonation velocity explosive (white regions) printed with a “slow” explosive (mustard-colored regions). These composite charges were detonated on one edge (one detonator on the left and two detonators on the right), and the detonation propagated along the longitudinal direction of the hemicylinders as indicated.

**Experimentation**

Two LDRD initiatives led to the development, design, and implementation of the first-ever explosives experiments at Argonne National Laboratory's Advanced Photon Source Dynamic Compression Sector, the OMEGA Laser Facility at the University of Rochester, and the National Ignition Facility. Performance and safety data on detonators and explosives were captured for the first time, improving the understanding of the materials' performance and aging. An artist's rendition depicts the experiment in which a laser impacts a thin HE material target (shown in yellow) and the chemical reaction results in solid-carbon products (black shapes).

**Safe Detonators**

The Laboratory invented and implemented the Mechanical Safe Arming Device (MSAD) and the Slapper detonator (below), which prevents accidental or unintended detonation of a nuclear warhead in National Nuclear Security Administration and DOD custody, as demonstrated in cut-back experiments with LX-21 (above). MSAD is a discriminator stronglink—a critical component for nuclear safety requirements—that protects the nuclear weapon by preventing any potential activation from outside sources.

**Diagnostics**

Livermore developed handheld explosive detection protocols, some of which have been commercialized. Improvements are ongoing with two patents granted since 2018. Pictured above is the pocket-sized E.L.I.T.E.™ (Easy Livermore Inspection Test for Explosives) kit—a 2016 R&D100 Award winner and Federal Lab Consortium Award winner—uses chemical reactions to quickly detect explosives.

The Livermore Explosives Detection Program provides end-to-end characterization of explosives and other threats including algorithm development to enable the Department of Homeland Security and the Transportation Security Administration to identify suspicious items in checked bags and differentiate explosives from harmless items. At left are samples of computerized tomography data from samples prepared and characterized by EMC and Non-destructive Characterization Institute scientists at HEAF.

**Publications**

EMC's High Explosives Reference Guide, following on from the first HE Handbook developed at EMC, is the standard for the documentation and distribution of critical explosives manufacturing, performance, and safety data and serves more than 1,300 users from the National Security Enterprise, DOD, and other government agencies. EMC also co-edits Pyrotechnics, the largest scientific journal in the field.

**Key Words:** Department of Defense (DOD), Department of Energy, Department of Homeland Security, Energetic Materials (EM), Energetic Materials Center (EMC), Energetic Materials Development Enclave, High Explosives Applications Facility (HEAF), LX-21, National Nuclear Security Administration, nuclear test ban, PBX 9502, Propellant, Explosives, Pyrotechnics, the largest scientific journal in the field.

Looking toward the 2030s and beyond, the center aims to enable the study of a reacting material at nanoscale resolution and micrometer-length scales not previously possible. Future advances require scrutiny of predictive codes, taking advantage of graphics processing unit architectures and applying machine learning and artificial intelligence. Other priorities include diagnostics to measure the temperature and product set of chemical reactions in situ at these shorter time and length scales; accelerated materials development through responsive and agile manufacturing and data science techniques; and development of new HE molecules by leveraging high-performance computing, computational chemistry, and scalable manufacturing processes. Aggressive schedules have called for increased testing at a pace not seen for decades, and EMC plans to remain the first place the National Nuclear Security Administration, DOD, and other government agencies think of when they need energetics expertise. Says Leininger, “After 30 years, the Energetic Materials Center is ready and agile for whatever comes next.”

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**Energetic Materials Landmarks**

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**Research Highlights**

**Disruptive Research**

**EMBRACING RISK FOR TRANSFORMATIONAL RESULTS**

THE Department of Energy’s Laboratory Directed Research and Development (LDRD) Program has been an engine of discovery for almost 30 years, investing in research that strengthens and advances Livermore’s core competencies, develops future scientific leaders, and grows Livermore’s intellectual property catalog. In 2018, the Laboratory initiated a pilot program for Disruptive Research (DR) projects to support the pursuit of exceptionally innovative ideas with the potential to open new research directions. “All LDRD projects are high-risk, high-reward,” says LDRD Program Director Doug Rottman. “In designing the DR pilot, we sought even more unconventional ideas, motivating the entire Laboratory to embrace scientific and technical risk to achieve mission-critical, transformational results.” An interdisciplinary committee developed the pilot and crafted a call for proposals focused on disruptive ideas and high-risk tolerance. DR proposals identify the largest barrier to project goals and a strategy to surmount that barrier as early as possible, while also charting go-no-go decision points along the way.

After down-selecting from the more than 80 white papers received, the committee selected nine proposals for the initial round of DR funding—between $400,000 and $2 million per year for up to three years. Project mentors meet with each team quarterly to discuss ideas, challenges, solutions, and exit strategies. “As scientists, we’re trained to look for risk-mitigation strategies,” says Materials Engineering Division Leader Chris Spadaccini, DR committee chair. “When designing the DR program, however, we took a different approach to managing risk. We hoped to inspire culture change at the Laboratory by investing in high-risk ideas and, if appropriate, accepting that researchers move on when results point in a different direction.” The following projects, now in their third year of funding, represent the breadth and creativity of Livermore researchers selected for the pilot program.

### Outside the Black Box

Historically, physicists have described fundamental knowledge using equations from which they derived follow-on discoveries. “From a simple physics equation like ‘force equals mass times acceleration $(F = ma)$,’ you can, by inspection, glean insights and understanding about the underlying physical process,” says computer scientist Brenden Petersen, who leads one of the DR projects. Artificial intelligence (AI), however, generates data without providing any interpretation. Deriving a mathematical expression to fit a data set—a problem known as “symbolic regression”—presents a challenging task for AI.

Models used in deep learning, a branch of machine learning that relies on neural networks to perform complicated functions such as image recognition, are considered black boxes. Researchers cannot easily interpret a neural network or explain its decision making. Petersen asks, “Can we use neural networks, these large models, to derive a small model—a mathematical equation—that makes predictions about the data?” The answer turns deep learning on its head. His team developed algorithms that use large neural network models to generate simple equations—not large, opaque models—and discard the neural network in the end. This disruptive concept leverages the power of deep learning while bypassing the need to interpret a neural network.

Petersen’s team has developed and tested an algorithm that uses a recurrent neural network (RNN) to randomly generate mathematical expressions as sequences then train the model to generate better-fitting expressions. Each item in the sequence—whether a variable or a mathematical operator such as cosine—is drawn from a library of tokens. The algorithm samples expressions and trains the model using fitness to the data set as a learning signal. A paper describing the team’s work ranked fifth out of nearly 3,000 submissions to the 2021 International Conference on Learning Representations.

The algorithm has broad applications such as learning interpretable strategies for optimal control or designing antibodies to bind to a particular pathogen. In this application, different amino acids take the place of operators like sine and cosine, and the algorithm uses binding affinity as a learning signal. In the project’s final year, the team will test their framework for other discrete optimization problems.

### Quantum Computing Leap

The collisions of atomic nuclei, and their constituent neutrons and protons (collectively called nucleons), power the evolution of stars and other astrophysical phenomena, create most of the universe’s elements, and inform nuclear weapons stockpile stewardship. However, even with today’s most powerful high-performance computing (HPC) machines, nuclear dynamics simulations add a high degree of difficulty as one additional function such as image recognition, are considered black boxes. Researchers cannot easily interpret a neural network or explain its decision making. Petersen asks, “Can we use neural networks, these large models, to derive a small model—a mathematical equation—that makes predictions about the data?” The answer turns deep learning on its head. His team developed algorithms that use large neural network models to generate simple equations—not large, opaque models—and discard the neural network in the end. This disruptive concept leverages the power of deep learning while bypassing the need to interpret a neural network.

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The algorithm has broad applications such as learning interpretable strategies for optimal control or designing antibodies to bind to a particular pathogen. In this application, different amino acids take the place of operators like sine and cosine, and the algorithm uses binding affinity as a learning signal. In the project’s final year, the team will test their framework for other discrete optimization problems.

Livermore researcher Sofia Quaglioni leads a DR project to develop methods for performing complex nuclear calculations on a prototype quantum computer.

Livermore’s Sierra computer, one of the world’s fastest systems at 125 petaflops (125 trillion floating-point operations per second), represents a giant step over the Laboratory’s first supercomputer, the Univac, installed in 1953.
Probability number of continuous gates—discrete, preset quantum-logical quantum computing test bed. The protocol employs a minimal then demonstrate nuclear dynamics simulations on Livermore’s the qubits. Quaglioni’s DR project set out to establish an processor perturb and disrupt the operational fidelity of in the equipment and in the environment around the quantum computers are still very experimental and, like the states known as qubits to encode and process an exponentially The jump from classical to quantum computers could be as great a leap in computing power. Quantum computers use quantum states known as qubits to encode and process an exponentially larger amount of information than classical computers using bits, making them ideal to simulate nuclear dynamics. “However, quantum computers are still very experimental and, like the vacuum tube circuits of the 1950s, prone to error,” says Quaglioni. Sources of noise from uncontrollable physical processes in the equipment and in the environment around the quantum processor perturb and disrupt the operational fidelity of the qubits. Quaglioni’s DR project set out to establish an unconventional protocol resilient to the quantum noise and then demonstrate nuclear dynamics simulations on Livermore’s quantum computing test bed. The protocol employs a minimal number of continuous gates—discrete, preset quantum-logical operations—customized to realize the desired nuclear dynamic interaction rather than long sequences of gates typical in quantum computing. The team has tested its approach, demonstrating the evolution, with time, of two interacting neutrons. “Our simulation achieved more than 99 percent fidelity and a one-hundred-fold improvement in simulation time—500 timesteps versus less than six—compared to previous simulations on digital quantum computing platforms,” says Quaglioni. The relatively simple two-particle simulation benchmarks the method’s performance. The protocol developed will increase quantum simulation capabilities by multiple orders of magnitude, enabling near-term quantum computing platforms to address a broad class of problems. “Quantum computers offer the promise of a unified approach to nuclear dynamics simulations from 5 to 250 nucleons,” says Kyle Wendt, a staff scientist working with Quaglioni. “The same simulations would require hundreds of millions of hours of computer time on a classical, digital HPC system.”

**Plasma Optics for Brighter Lasers**

The first lasers used crystals to generate beams of coherent light, earning a Nobel Prize for the inventors. By the late 1960s, lasers reached intensities of $10^{13}$ watts per square centimeter (W/cm²). With the invention of chirped pulse amplification, ultrashort laser pulses can be amplified up to $10^{19}$ W/cm². (Donna Strickland, who worked at Livermore, shared the Nobel Prize for this development.) Further intensity increases have stalled because forcing more energy through solid laser optics damages the optics material or causes it to shatter. A DR project led by Patrick Poole aims to significantly increase laser power and intensity using plasma as the amplifying medium.

Plasma optics can be generated and manipulated, replacing conventional solid optics that have reached damage thresholds. Poole’s work takes a new approach to optics that builds on recent research at Livermore’s National Ignition Facility (NIF). A team of investigators combined several laser beams within a plasma (a high-temperature gas of ions and electrons) to create a single beam of 10 times higher energy than the original seed beam. Plasma optics advanced the power and intensity of lasers, boosting their ability to probe the physics of matter and energy. Poole’s team has developed a plasma optic using a 10-millimeter plastic balloon filled with C$_5$H$_{12}$ (pentane) gas, irradiating it with a cluster of laser beams in a prescribed sequence, heating the gas to a plasma, generating a high electron density, and then producing the output beam. In experiments at NIF, the researchers combined 21 laser beams into one with almost three times the intensity a single NIF beam could produce without damaging its solid optics. The team has demonstrated that the combined beam maintains its focusing properties after amplification, meaning it can be used for high-energy, single-beam applications, such as where the target is too small to allow many beams inside.

With project milestones already reached—to create a higher energy beam with the high focus required for experimental use—the researchers will model and execute an experiment that produces a second plasma optic to reduce pulse time to below 88 picoseconds and use more plasma to boost the shorter pulse to even higher power. By focusing this amplified light at about $10^{20}$ W/cm², the research team hopes to demonstrate the possibility that beams can exceed the thresholds anticipated for next-generation, high-intensity laser facilities. “A number of applications at NIF could use a beam of this intensity to unlock new physics,” says Poole.

**More Results on the Horizon**

Beyond the potentially high-impact results of the LDRD Program’s inaugural DR projects, the researchers’ work has attracted follow-on research at Livermore. Project teams have also gained important information from the experimental paths that do not go as planned. “Disruptive research involves risk, and we understand that some projects will not attain their original goals,” says Rotman. “Our message to investigators, and everyone at the Laboratory, is that pushing the envelope is great, and we should applaud efforts to spark transformative change. The teams leading our first group of DR projects have embraced these values to achieve truly disruptive research and results.”

—Allan Chen

**Key Words:** chirped pulse amplification, deep learning, disruptive research (DR), Laboratory Directed Research and Development (LDRD) Program, laser, machine learning, National Ignition Facility (NIF), neural networks, nuclear dynamics, nucleon, plasma amplifier, quantum computer, qubit, recurrent neural network (RNN), Sierra, Univac.

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In this section, we list recent patents issued to and awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory. For the full text of a patent, enter the seven- or eight-digit number in the search box at the U.S. Patent and Trademark Office's website (https://www.uspto.gov).

## Patents

### Compounds for Reactivation of Acetylcholinesterase and Related Compositions, Methods, and Systems
Carlos Valdez, Nicholas Be, Brian Bennion, Tim Carpenter, Heather Enright, Felice Lightstone, Mike Malfatti, Margaret McNerney, Tuang Nguyen
10,935,780 B2
March 17, 2020

### Integrated Telescope for Imaging Applications
Reginald Beer, David Chambers, Hema Chandrasekaran
10,935,635 B2
March 2, 2021

### Object Discrimination Based On a Swarm of Agents
Andrew James Bayramian, Kenneth Manes, Robert Deri, Al Erlandson, John Caird, Mary Spaeth
10,930,067 B2
February 23, 2021

### Electrochemical Flow-Cell for Hydrogen Production and Nicotinamide Dependent Target Reduction and Related Methods and Systems
Patrick Campbell, Eric Duoss, James Oakdale
10,868,325 B2
March 30, 2021

### System and Method for Enhanced Visualization of Near Surface Vascular Structures
Stavros Demos
10,937,869 B2
March 9, 2021

### Microporous Membrane for Stereolithography Resin Delivery
Joshua Deece
10,946,580 B2
March 16, 2021

### Gene-Techs Engineered Foot and Mouth Virus and Related Proteins, Polynucleotides, Compositions, Methods, and Systems
Aida Reider, Teresa De Los Santos, Luis Rodriguez, Devendra Rai, Fayna Diaz-San Segundo, Paul Hoeprich
10,953,085 B2
March 23, 2021

### Non-Destructive, In-Situ Evaluation of Water Presence Using Thermal Contrast and Cooled Detector
Mihail Bora
10,962,417 B2
March 30, 2021

### Click-Chemistry Compatible Structures, Click-Chemistry Functionalized Structures, and Materials and Methods for Making the Same
Patrick Campbell, Eric Dussa, James Oakdale
10,962,879 B2
March 30, 2021

### Preparation of Large Ultrathin Free-Standing Polymer Films
Michael Stadermann, Salmaan Baxamusa, William Floyd III, Phillip Miller, Taysab Surawala, Anatoliis Tamadzidze, Kelly Youngblood, Chantel Aracne-Ruddell, Art Nelson, Maverick Chea, Shuail Li
10,965,325 B2
April 6, 2021

### System and Method for Focal-Plane Illuminator/Detector (FASID) Design for Improved Graded Index Lenses
Jeffrey Bude, Eyal Feigenbaum
10,969,300 B2
April 6, 2021

## Awards

### Bronis R. de Supinski, chief technology officer for Livermore Computing (LC), was named one of HPCwire’s People to Watch, a list of top influencers in the high-performance computing industry for 2021. The magazine recognized de Supinski, a two-time Gorden Bell Prize winner, for his work in devising and executing Livermore’s large-scale high-performance computing strategy including the upcoming exacscale-class system, El Capitan, and his selection as general chair for the 2021 International Conference for High Performance Computing, Networking, Storage, and Analysis (SC21).

#### About the award

Three Lawrence Livermore postdoctoral appointees—Oluwatomisi (Tomi) Akindele, Matthew Edwards and Wei Jia Ong—were selected to attend the 70th annual Lindau Nobel Laureate meeting, an international forum in which students and postdocs meet with 30 to 40 Nobel laureates to foster an exchange among scientists of different generations, cultures, and disciplines. Akindele researches the use of antimicrobials to detect the operational status of a nuclear reactor at a distance. Edwards studies light and plasma applied to building next-generation lasers and accelerators. Ong applies an interdisciplinary approach to investigate the origins of heavy elements in the cosmos.

### Planetary Research: Exploring our Past and Future

As represented by the work of four Lawrence Livermore research teams, the Laboratory’s foundational research in astrophysics, nuclear science, cosmochemistry, and data science and its state-of-the-art facilities yield a fascinating range of discoveries that inform the origins of space and generate tools for new breakthroughs. A computational chemist leads research to simulate past extraterrestrial events, such as cometary impact, that sparked the organic precursors of early biomolecules, and, ultimately, the building blocks of proteins. In other work, cosmochemists use nuclear forensics to study meteorites and Moon rock samples from the Apollo missions to understand the sequence and timing of the solar system’s evolution. A collaborative team from Livermore and Johns Hopkins University Applied Physics Laboratory develops gamma-ray spectrometers small enough to hold in one hand yet rugged enough to operate onboard vehicles exploring the moons of Mars and Saturn. Finally, Laboratory materials scientists study meteorite specimens to propose welding technologies for building colonies in space and on other planets. As these, and similar, research projects progress, the nation and the world will gain more answers to questions about our past and our future in space.

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### Coming Next Issue

- Advanced computer models, simulations, and analysis capabilities help scientists zoom in on earth-system processes and improve climate research.

### Also in the next issue

- Tools to support data processing workflow reveal the multifaceted nature of traumatic brain injury.
- Lawrence Livermore’s Distinguished Member of Technical Staff Program awards leaders on the scientific career path.
- Nanosatellites take thousands of images of space and Earth thanks to a Laboratory–industry partnership.
Also in this issue:
Laboratory Operations in a Pandemic
Energetic Materials Center Anniversary
Disruptive Research Results