Science & Technology Review
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Lawrence Livermore National Laboratory

Science & Technology REVIEW

June 2016

HONORING TALENTED TECHNICAL STAFF

Also in this issue:

Natural Enzyme Helps Trap Methane

Improving Neural Networks for Machine Learning

An Explosive Solution to Oceanic Oil Spills

About the Cover

In 2015, Lawrence Livermore implemented the Early- and Mid-Career Recognition (EMCR) Program to recognize and reward outstanding scientists and engineers who earned their highest university degree between 5 and 20 years ago. Winners receive a cash award and one year of funding for up to 20 percent of their time to pursue exploratory research activities in their area of interest. The article beginning on p. 4 highlights the achievements of 5 of the 15 EMCR awardees selected in the program's inaugural year. These individuals are featured on the cover and include (from left to right) Kumar Raman, Carol Woodward, Brian Pudliner, Manyalibo (Ibo) Matthews, and Nathan Barton. Their research spans a wide range of scientific areas, methods, and applications, and all of them have made notable contributions to Livermore's missions and to science.

Cover design: Tom Reason; Photography: Lanie L. Rivera

About *S&TR*

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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NNSA National Nuclear Security Administration

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June 2016

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Visualizing High-Energy Electrons in Fast Ignition

Recent fast-ignition (FI) research by an international team of scientists, including researchers from Lawrence Livermore, produced the first visualization of fast-electron spatial energy deposition in a laser-compressed, cone-in-shell FI target. The research was published in the January 11, 2016, issue of *Nature Physics* and opened the door for optimizing the FI target design. The paper's lead author is Charlie Jarrott, who recently joined Livermore as a postdoctoral researcher.

FI is an alternative approach to conventional inertial-confinement fusion that involves separating the compression and heating phases of implosion. This separation allows fuel to be compressed isochorically, resulting in reduced fuel density requirements or increasing the mass of fuel that can be compressed, potentially leading to higher gain. The process requires efficient heating of precompressed, high-density fuel by an intense, relativistic electron beam produced from laser–matter interactions. To facilitate FI research, scientists doped the shell of the cone-in-shell FI target with copper and imaged the K-shell x-ray radiation.

The experiments showed the spatial distribution of fast electrons and revealed key parameters affecting energy coupling. The results also exhibited a significantly improved laser-to-core coupling energy efficiency of seven percent—a factor-of-four improvement over previous results using similar techniques and the highest coupling efficiency ever reported with the Omega Laser Facility at the University of Rochester, where the experiments were conducted. The experiments' success has the far-reaching implications of applicability to megajoule-scale laser facilities such as Lawrence Livermore's National Ignition Facility.

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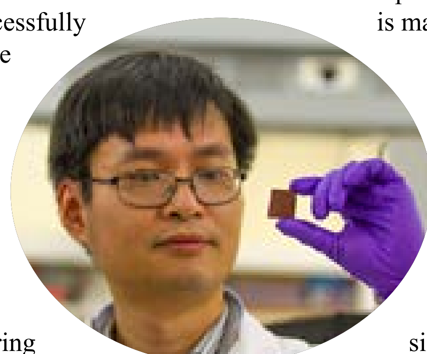
Printing Three-Dimensional Supercapacitors

For the first time, scientists at Lawrence Livermore and the University of California at Santa Cruz have successfully used a three-dimensional (3D) printing technique to create supercapacitors made from ultralight graphene aerogel. Their results were published on January 28, 2016, in the online journal *Nano Letters*. The research opens the door to novel, unconstrained designs of highly efficient energy-storage systems for devices such as smartphones, implantable devices, electric cars, and wireless sensors. "This breaks through the limitations of what two-dimensional manufacturing can do," states Livermore engineer Cheng Zhu, the paper's lead author (shown in photo holding a supercapacitor).



Using a 3D printing process called direct ink writing and a graphene-oxide composite ink designed at the Laboratory, the scientists printed microarchitected electrodes and built supercapacitors with an energy capacity similar to those made with electrodes 10 to 100 times thinner. This method of using graphene-based inks to produce 3D supercapacitors has multiple benefits. They provide an ultrahigh surface area, are lightweight, and exhibit elasticity and superior electrical capacity. Supercapacitors can also charge remarkably fast. In addition, the graphene-composite aerogel supercapacitors are extremely stable and can retain their energy capacity after 10,000 consecutive charge–discharge cycles.

"Additively manufactured 3D architectures for energy storage will improve energy and power characteristics for supercapacitors, enabling lightweight, miniaturized power sources," says Livermore materials engineer Eric Duoss. The implications of the study are vast—Zhu and his fellow researchers believe newly designed 3D-printed supercapacitors will be used to create unique electronics in the future, such as fully customized smartphones and paper-based or foldable devices while concurrently achieving unprecedented levels of performance.

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Shock Waves Induce Protein Damage in TBI Patients

New research by Lawrence Livermore scientists has revealed how shock waves can damage membrane proteins in traumatic brain injury (TBI) patients. The research appears in the January 5, 2016, edition of *Biophysical Journal*.

Blast-induced TBI is the most frequent wound produced from conflicts in Afghanistan and Iraq, but it has never been clear how energy from a blast is transmitted to the brain. To better understand this process, Livermore physicists Edmond Lau and Eric Schwegler, along with University of North Carolina colleague Max Berkowitz, used molecular dynamics simulations to examine the effects of shock waves on the brain. The researchers found that shock waves alone do not significantly damage ion channels, but with the presence of bubbles, the shock wave–induced damage is magnified.

Previous simulations of bubble–shock interactions have shown that the force generated by bubble collapse can cause pore formation in membranes. These pores likely lead to unregulated ion exchange, causing an imbalance within cells that can eventually lead to the initial symptoms of TBI, such as headaches and seizures.

Other molecular simulations have shown that membranes can self-heal from nanometer-sized pores in tens of nanoseconds. Ion channels, on the other hand, may not self-heal as rapidly. "Ionic imbalances likely play an important role in the cellular damage incurred from TBI," says Schwegler.

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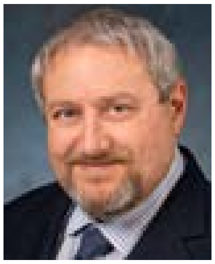
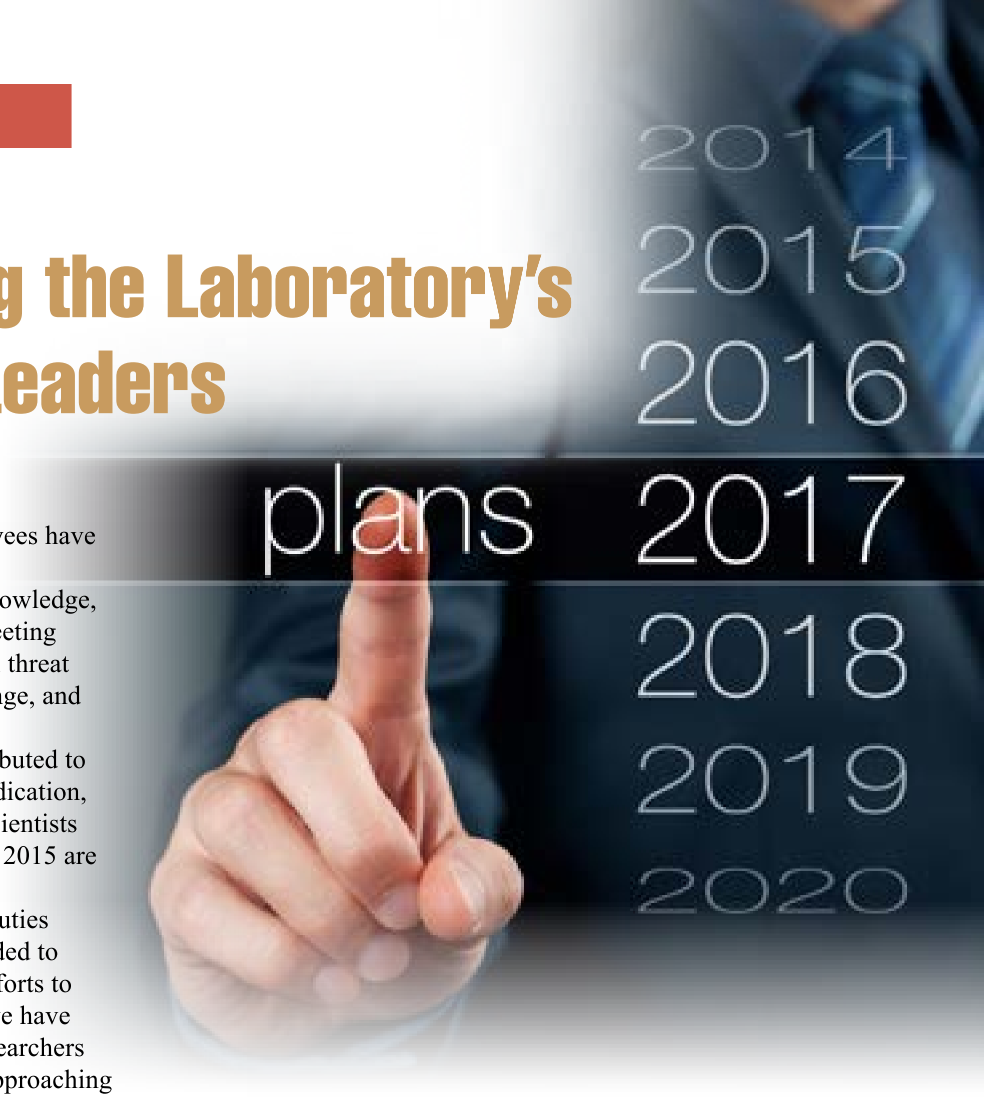
Commentary by William H. Goldstein



Recognizing the Laboratory's Emerging Leaders



FOR more than 60 years, Lawrence Livermore employees have applied science and technology to make the nation—and the world—a safer place. Our employees' skills, knowledge, and enthusiasm are essential to continued success in meeting formidable challenges in national security, international threat reduction, stability, energy technology and climate change, and human progress.

The numerous awards, honors, and publications attributed to Livermore employees are indicative of their quality, dedication, and innovative spirit. For example, the 10 Livermore scientists selected as fellows of the American Physical Society in 2015 are evidence of the Laboratory's capability and influence.

As Laboratory Director, one of my most important duties is to ensure that we continually revitalize the skills needed to fulfill our mission responsibilities through concerted efforts to attract and develop an exceptional staff. Accordingly, we have instituted a number of programs to prepare younger researchers to take on leadership roles filled by experienced staff approaching retirement age.

A new addition to this effort, launched in 2015, is the Early- and Mid-Career Recognition Program, which is designed to help younger researchers enrich their careers and receive the full recognition they deserve. As detailed in the article beginning on p. 4, this program honors up to 15 scientists and engineers annually for their significant technical accomplishments and leadership potential. The recipients receive a cash award and funding to pursue a research interest outside their demanding programmatic assignments, which are too often all-consuming.

The call for nominations last year yielded 99 outstanding nominees who were evaluated based on the quality of their technical contributions, the influence of their work, and their leadership abilities. The committee that evaluated the nominations, composed of distinguished members of the technical staff, reported that choosing the first class was a daunting challenge because of the quality of the pool. Based on that feedback, 2015 nominees who were not chosen, but are still eligible, will be automatically considered in the next round.

Feedback from the first class of recipients indicated that they were genuinely surprised, appreciative, and honored. In my view, they represent well the extraordinarily wide range of research programs pursued at Livermore as well as the very highest standards of research and development. They also continue to garner recognition. For example, plasma physicist Félicie Albert recently won a Department of Energy Office of Science Early Career Research Program award.

Outstanding young researchers continue to be drawn to Lawrence Livermore by the opportunity to work at state-of-the-art research facilities on exciting projects with colleagues who are leaders in their respective fields. However, we face a unique challenge in keeping the best and the brightest because of the stiff competition for talent in the San Francisco Bay Area. Our competitors include many strong and innovative companies in Silicon Valley, as well as major universities such Stanford and the University of California at Berkeley. Nevertheless, the Laboratory was recently named to the 2016 Forbes list of America's Best Large Employers, with a ranking of 102 out of 500 top employers across the country. In the San Francisco Bay Area, we placed in the top 10.

A committee composed of distinguished members of the technical staff is currently reviewing this year's nominees to select the class of 2016 Early- and Mid-Career Recognition Program recipients. With programs such as this, we will continue to recognize, reward, and retain the outstanding scientists and engineers needed to fulfill our broad national security mission.

■ William H. Goldstein is director of Lawrence Livermore National Laboratory.

A Salute to Promising Technical Staff

An annual recognition program promotes retention and job satisfaction and encourages creative problem-solving in the next generation of technical staff.

THE challenges of Lawrence Livermore's national security mission demand a workforce of exceptionally skilled and dedicated employees. Attracting, retaining, and celebrating the achievements of such an adept workforce is an ongoing priority for the Laboratory. In 2015, Lawrence Livermore introduced an annual recognition program for outstanding scientists and engineers in the formative stages of their careers that acknowledges their technical achievements, provides opportunities to

pursue new ideas, and helps them prepare for technical leadership roles as their careers progress.

The Early- and Mid-Career Recognition (EMCR) Program rewards outstanding Livermore scientists and engineers who earned their highest university degree between 5 and 20 years ago. Nominations are solicited once a year and may come from the candidates' managers, peers, or the people they supervise. A screening committee, convened by the deputy director for science and technology (DDST) and selected from distinguished members of the technical staff (a permanent designation bestowed upon a small group of exceptional senior scientists and engineers), reviews the nominations and produces a list of up to 15 candidates for evaluation and selection by the Laboratory director. Winners receive a cash award and one year of funding for up to 20 percent of their time to pursue a research project of their choice.

The director of Livermore's Science and Technology Assessments Office,

Early- and Mid-Career Recognition Program recipients include (from left) Kumar Raman, Carol Woodward, Brian Pudliner, Manyalibo (Ibo) Matthews, and Nathan Barton. (Photo by Lanie L. Rivera.)

Ken Jackson, who led the 2015 screenings on behalf of DDST, notes, "We received 99 nominations last year. They were all strong candidates and the majority of them outrageously so. Having so many highly qualified nominees made me appreciate how truly exceptional our early- and mid-career workforce really is." Nominees are evaluated on the originality and effectiveness of their scientific endeavors; the influence of their work in their given field, which is based on publications, presentations, or other recognition by the scientific community; and their leadership abilities—including how they work as part of a technical team. Screening committee member Omar Hurricane explains, "Lawrence Livermore is successful in its missions because it brings together skilled investigators to solve problems on a scale that would not be possible for a single researcher. This unique team approach makes us stronger." In this spirit, many of the winners emphasized that their recognition by this program represents not only their work but the contributions of their colleagues and collaborators.

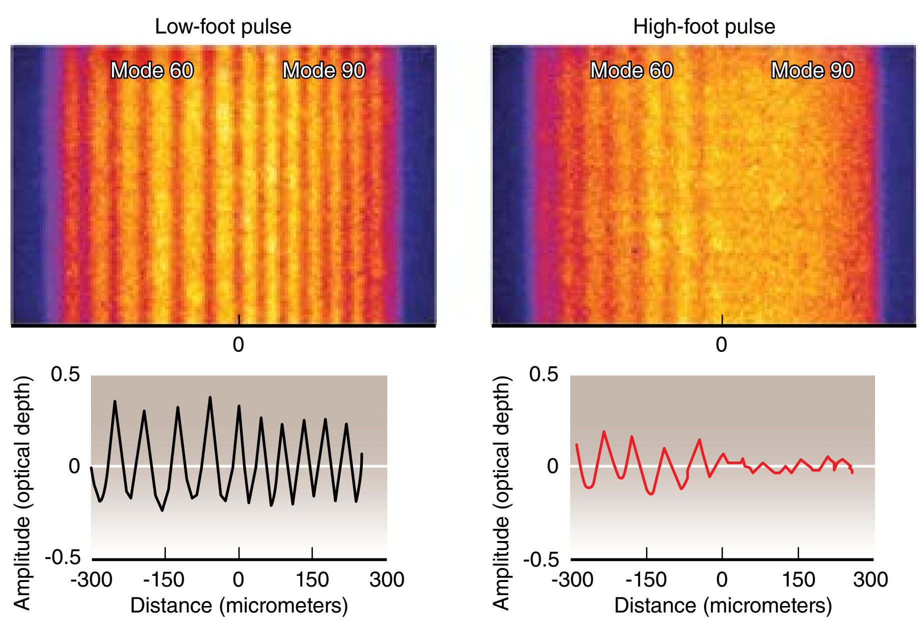
EMCR awardees selected in the program's inaugural year include Félicie Albert, Nathan Barton, Stefan Hau-Riege, John Heebner, Sergei Kucheyev, Felice Lightstone, Stephan MacLaren, Manyalibo (Ibo) Matthews, Miguel Morales-Silva, Jennifer Pett-Ridge, Brian Pudliner, Kumar Raman, Dawn Shaughnessy, Vanessa Tolosa, and Carol Woodward. Five of these 15 recipients are profiled in this article. They include a mathematician, three physicists, and a materials scientist, and their research analyzes phenomena at a range of length and timescales, with applications as diverse as water resource management and nuclear fusion, and all have made substantive technical contributions to the Laboratory's missions and to their respective fields.

Supporting Experimental Success

Physicist Raman helps design, simulate, and analyze weapons and fusion experiments for one-of-a-kind facilities such as Livermore's National Ignition Facility (NIF) and Sandia National Laboratories' Z machine. This role requires regular collaboration with engineers, experimentalists, computer scientists, facilities staff, and manufacturing specialists. "Designing experiments is an integrating activity," says Raman. "Part of the challenge involves identifying experiments that affect the broader mission and then working as part of a technical team to execute them."

Each experiment at NIF, for instance, requires months of preparation and target development and can involve coordinating an integrated suite of capabilities such as laser parameters, targets, and diagnostic tools—collectively called a platform. Raman helps teams make the most of their precious facility time allocation by running simulations of the proposed experiment to help identify constraints and possible outcomes and by using that information to optimize the setup.

In NIF fusion ignition experiments, laser energy is focused on the inside walls of a metal cylinder and converted into x rays, which heat and vaporize the plastic surface of a peppercorn-size fuel capsule mounted at the cylinder's center. The capsule rapidly implodes, compressing the deuterium–tritium fuel and causing it to heat. Creating



(top) Hydrodynamic growth radiography experiments use x rays to image the development and growth of hydrodynamic instabilities during the implosion of rippled-surface targets for (left) low-foot laser pulses and (right) high-foot laser pulses. (bottom) Consistent with model predictions, the evolution of ripple wavelength and amplitude shows that high-foot pulses generated significantly less perturbation growth than low-foot laser pulses.

conditions under which this heating initiates a self-sustaining burn—ignition—has been a decades-long quest. One of the most significant challenges to achieving ignition with NIF involves understanding and controlling hydrodynamic instabilities in the capsule during compression.

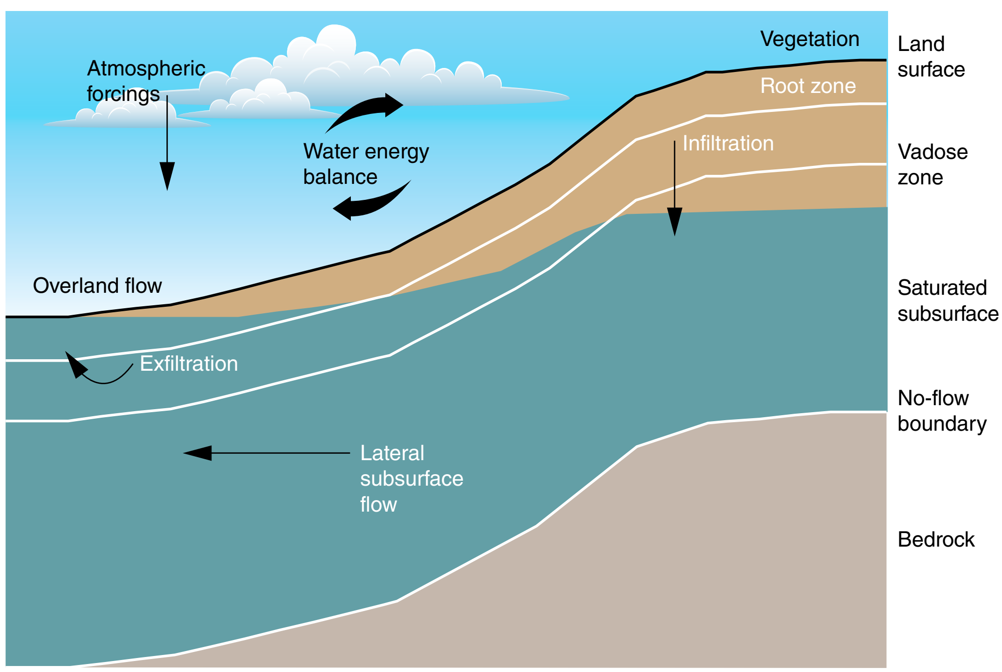
A career highlight for Raman was leading the design effort to develop a NIF radiography platform to measure the growth of Rayleigh–Taylor and Richtmyer–Meshkov hydrodynamic instabilities in fusion capsules. (See *S&TR*, June 2014, pp. 4–10.) Hydrodynamic growth radiography (HGR) experiments, which have the same capsule design as those used for ignition but with a rippled outer surface and without the fuel, aim to address this challenge. Raman and colleagues successfully used the HGR platform to compare fusion capsule instability growth with simulations performed during the National Ignition Campaign (NIC). This work was part of an effort to understand why NIC capsules did not reach ignition conditions despite achieving ignition-relevant implosion velocities. (NIC ended in 2012.) They found that measured instability growth was consistent with model predictions for the applicable laser pulse shapes. Low-foot pulses were used during NIC, and later, high-foot pulses were introduced after studies revealed they are less prone to hydrodynamic instabilities. A National Nuclear Security Administration Defense Programs Award of Excellence presented to the Livermore high-foot team in 2014 cited HGR experiments in helping validate the efficacy of the high-foot pulse shape.

Raman has since moved on to other projects, but his work developing the HGR platform continues to benefit NIF research. Raman says, "Hydrodynamic instabilities are a concern for any of our ignition designs. It is important both to model them accurately and to develop strategies to mitigate their deleterious effects. It is gratifying to see the HGR platform being used to inform this process."

Algorithms Improve Codes

Computational mathematician Woodward creates, refines, and integrates algorithms into scientific codes designed to run on high-performance computing machines. Her specialty is developing algorithms for calculating the solutions to nonlinear systems of equations and time integration methods—numerical methods that step a time-dependent mathematical model forward—that improve application efficiency and robustness. Woodward's collaborations with scientists have made possible the first-ever or largest simulations in many different research areas, from astrophysics to geoscience.

Some of Woodward's most significant contributions have stemmed from the groundwater-modeling project that drew her to the Laboratory. "Geoscience problems are what I enjoy working on the most," she notes. Early in her tenure, she modified the Livermore-developed ParFlow code, which is used for large-scale, three-dimensional groundwater simulations of saturated flow (the flow of water below the water table). Woodward adapted the code to include variably saturated flow (the behavior of water as it trickles down to the water table). Hydrologist Andrew Tompson says, "Allowing the model to address groundwater flow processes over the entire subsurface was a tricky feat. The mathematics to describe flow in the 'unsaturated zone' above the water table was much more complicated and the parallelism of the model—its ability



The ParFlow code takes surface topography, such as hills and valleys, into account when modeling ground and surface water flow. An idealized hill slope is shown. (Image courtesy of Reed Maxwell, Colorado School of Mines.)

to take advantage of massively parallel computing resources—had to be preserved in the process. The result allowed us to address many complex problems involved in other projects."

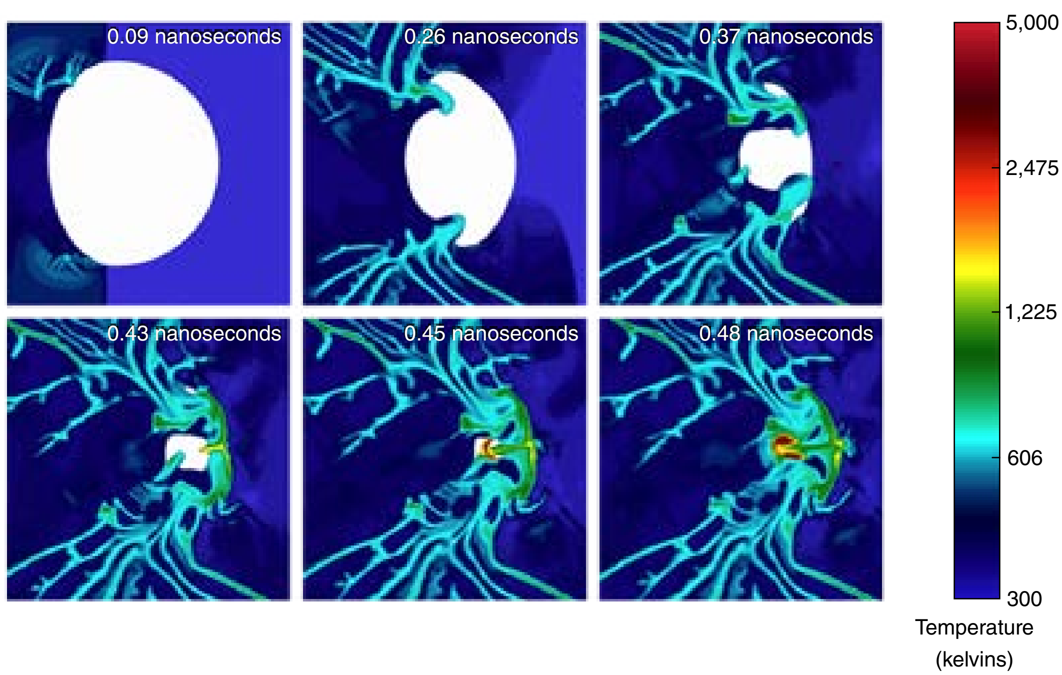
Woodward has continued to work with researchers such as Tompson and hydrologist Reed Maxwell at the Colorado School of Mines to enhance and apply ParFlow to various projects. By combining ParFlow with a land surface model, the team was able to efficiently model interactions between ground and surface water and account for topography in water flow. Later, the researchers coupled ParFlow with atmospheric and climate models in a novel approach to examine ground and surface water feedbacks to the atmosphere. They have even used ParFlow to develop more accurate simulations of low-level winds for wind farm locations by accounting for soil moisture levels, which influence soil temperature and thus wind speed. Researchers worldwide now apply the code for climate analysis and water resource management. Woodward is currently involved in a Department of Energy (DOE) project to implement ParFlow for high-resolution ground and surface water simulations of the entire continental United States.

Woodward also leads development and deployment of Lawrence Livermore's Suite of Nonlinear and Differential/Algebraic Equation Solvers (SUNDIALS), a package of time integrators and nonlinear solvers for large-scale problems. SUNDIALS garners more than 4,500 downloads annually and is used in numerous simulation-dependent applications. Woodward's technical contributions have modernized the software and upgraded its functionality so that it scales to DOE's highest-end computing systems. Her expertise in this area benefits her other projects, too. For instance, Woodward helped incorporate SUNDIALS packages into the Laboratory's transmission power grid simulator as well as the Parallel Dislocation Simulator. In addition, she is currently integrating several new solvers from SUNDIALS into ParFlow to improve the code.

Multiscale Makes Connections

Computational engineer Barton works at the intersection of materials science and computation. He leads a group of simulation experts who develop models and codes for exploring material behavior at a range of scales and collaborate with experimentalists to validate those models. His primary research interest is predicting and understanding materials strength and damage, using high-fidelity modeling, for a range of national security and stockpile stewardship applications.

Barton has contributed to developing and refining a multiscale strength model of the metals vanadium and tantalum. "Multiscale material modeling is a signature Livermore capability," he notes. Material properties such as strength often depend on phenomena that take place at a range of length and timescales. By combining atomic scale (nanometer), microscale (micrometer), and mesoscale



A multiphysics finite-element simulation provides a detailed view of an evolving microscopic pore in the energetic material HMX as the pore is hit by a shock wave and collapses. (Colors indicate temperature in kelvins.)

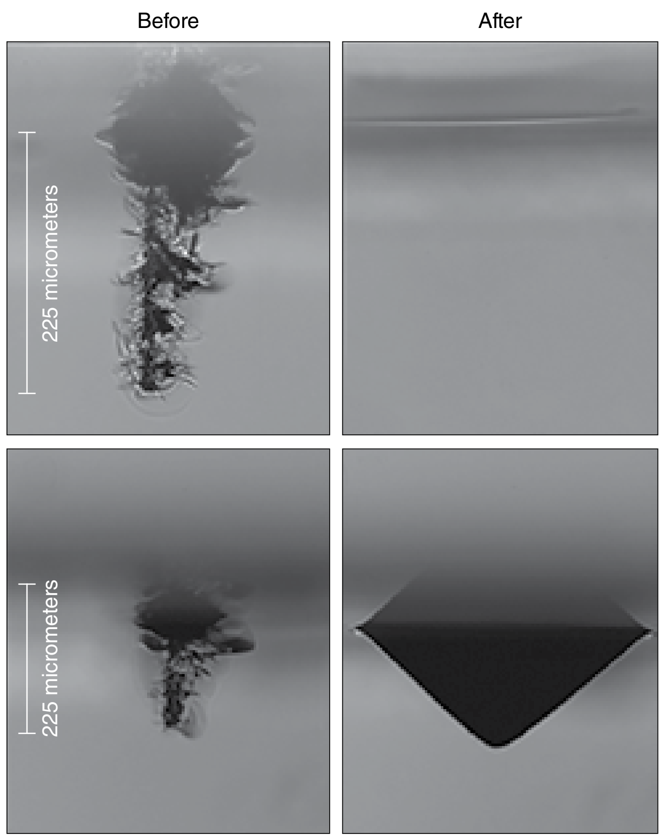
(millimeter and above) models, scientists can more accurately simulate the evolution of mechanical and chemical changes in materials. (See *S&TR*, December 2000, pp. 4–11; June 1999, pp. 22–25.) Barton's specialty is mesoscale continuum modeling. "Continuum is the scale at which we don't explicitly treat discrete defects in the material," he explains. "These models are part of an integrated code effort, where we look at stress and resistance to deformation and track the state of materials."

Barton and colleagues have compared multiscale model predictions with material strength data from high explosives-driven experiments performed at Los Alamos National Laboratory and laser-driven experiments conducted at NIF and the Omega laser at the University of Rochester's Laboratory for Laser Energetics in New York. The experiments induce the formation and rapid growth of Rayleigh–Taylor instabilities in a metal target. Such instabilities can occur at the interface between materials of different densities and are relevant to fusion, supernova, and stockpile stewardship research. By measuring the growth of ripples in the target surface, the researchers ascertain the sample's strength under an applied load, as weaker materials are less resistant to instability growth and generate larger ripples. (See *S&TR*, September 2015, pp. 20–23.) Livermore's model has accurately simulated experimental behavior and material evolution at a range of strain rates, pressures, and temperatures, including peak pressures of up to 140 gigapascals in tantalum and 100 gigapascals in vanadium.

Barton has also helped construct a computational framework for studying how crystalline energetic materials respond thermally, mechanically, and chemically when hit by a shock wave. The framework incorporates a novel continuum model for predicting how and when microscopic pores within the crystal structure will collapse, possibly leading to the formation of hot spots and initiating chemical reactions. Barton and colleagues have also created and tested a two-dimensional model of a single collapsing pore in the energetic material HMX at pressures up to 11 gigapascals and compared the results to a three-dimensional study and data from compression experiments performed with a gas gun. The model has aided researchers in identifying which methods of pore collapse are most significant. Chemist Larry Fried observes, "Nathan's crystal-level models give us unprecedented insight into the processes responsible for the safety of high explosives."

From Optics to Metal Manufacturing

Matthews is a physicist who applies his background in optical materials, laser–matter interactions, and spectroscopy to a wide range of projects from pulsed-laser optics damage to hydrogen storage to additive manufacturing (AM). Matthews is part of a research group tasked with characterizing, understanding, and finding ways to prevent damage to fused-silica optics on high-power lasers, particularly NIF, and to repair damage when it occurs. (See *S&TR*, September 2011, pp. 17–19.) He says, "We study a variety of laser–matter interaction problems for NIF and other applications, one of which involves using high-power lasers to process optics and repair laser-induced damage."



Livermore researchers have developed various methods of repairing flaws in fused-silica optics for high-power lasers. For example, (top) intense laser light is used to "heal" a damaged region through annealing and (bottom) to shape the damage into a well-defined, cone-shaped pit that will not interfere with laser experiments.

Laser-induced surface pits can limit laser performance and cause damage to other optics. Initial attempts to “heal” the flaws with laser light resulted in a rim around the pit that acted as a lens and promoted faster deterioration. Using experiments and finite-element analysis modeling to optimize wavelength, pulse length, power, and beam size, Matthews and his colleagues helped guide the development of a micromachining technique for mitigating this type of damage. The method uses a pulsed beam to scan back and forth across the affected surface, removing enough material to form a precise conical pit that will not damage other optics or affect experiments.

Matthews also helped develop a first-of-its-kind optics repair technique using laser chemical-vapor deposition—also known as gas-phase AM—that replaces missing silica with nanoscale precision. Both repair approaches have applications beyond silica glass. In fact, as part of an initiative funded by the Laboratory Directed Research and Development Program, Matthews has been applying methods and models developed for studying damage repair to selective laser melting (SLM), a metal AM technique. SLM uses a high-power laser and a digital blueprint to fuse layers of metal powder together and produce three-dimensional parts.

Matthews and his colleagues have been exploring how the laser interacts with the powder, how heat flows through the system, and how the characteristics of the laser itself influence the SLM process. (See

Laboratory researchers (from left) Matthews; Wayne King, director of Livermore’s Accelerated Certification of Additively Manufactured Metals Initiative; and engineering associate Gabe Guss show a three-dimensional part manufactured with the selective laser melting (SLM) system (shown in background).

S&TR, January/February 2015, pp. 12–18.) By learning more about the physics behind SLM, they aim to adjust laser parameters to achieve more precise results. For instance, using high-speed diagnostics to document simple SLM experiments, Matthews tracked the ejection of sparks from the fusing metal and discovered why denudation—missing material around the melt track—occurs. The team found that powder grains are pulled in toward the laser beam rather than pushed away from it, as previously assumed, in part because of the same physics effect that formed the pit rims on treated optics.

AM expert Wayne King observes, "Matthews' experimental work on the metal powder–bed fusion process is revealing physics that has been missing from our models and needs to be added. His work also has made a significant impression on the broader additive manufacturing community." Matthews' contributions continue through efforts such as a joint General Electric–Livermore project funded by America Makes, for which Matthews will be coordinating the development of open-source algorithms that produce more durable and uniform SLM parts.

An Unexpected Honor

Despite the significance of their efforts, Livermore researchers who mostly work on classified projects have less opportunity to develop a name for themselves in the wider scientific community because they are unable to publish their research in open scientific literature. Providing recognition and reward opportunities for these individuals is particularly important, notes Hurricane. Criteria for the EMCR Program were designed to allow individuals who primarily perform classified work to compete on equal footing with those who mainly conduct unclassified research, for example, by embracing a broader definition of what "publication" might entail. "So much excellent technical work goes on in classified areas, and it's especially gratifying for people working in those areas to be recognized because they are often the last to expect it," says Hurricane.

For EMCR awardee Pudliner, the honor was indeed unexpected. He notes, "Doing mission-oriented work, many of my day-to-day tasks aren't necessarily glamorous. It's often about helping other people get their work done." However, he finds the role rewarding and excels at his work. Pudliner, who has degrees in physics and computer science, develops multiphysics simulation codes and supports the Livermore researchers who use the codes for national security applications ranging from stockpile stewardship to nuclear counterterrorism to emergency response. Earlier in his Livermore career, Pudliner contributed to the completion of several key milestones for the Accelerated Strategic Computing Initiative, which demonstrated the feasibility of using large-scale parallel computing to perform simulations relevant to stockpile stewardship applications. "We arrived at a place where we were defining the state of the art for weapons codes," he notes. "Five years later, what previously seemed like heroic calculations became standard calculation types for our users."

New Leaders Emerge

Whether finding new applications for existing methods and models or seeking out novel ways to study long-standing problems, the 2015 EMCR Program awardees are making noteworthy technical contributions to the Laboratory. By allowing recipients to use up to 20 percent of their time to build on previous work, branch out in new directions, or do a little of each, the program aims to reward and encourage the creativity that has already enabled recipients to achieve success in their technical careers. With his time allotment, Raman is modeling NIF nuclear diagnostics to better understand and interpret the data they produce. Woodward and Pudliner are working on new algorithms. Barton is exploring how complex high-fidelity models can exploit novel computer architectures presently under development, while Matthews is designing a method for optimizing microstructural topology in additively manufactured metal structures.

The EMCR Program is more than just recognition of past accomplishments—it is an expectation of future successes. As the average age of Livermore employees continues its upward trend and more experienced researchers approach retirement, skilled younger researchers must be prepared and motivated to take on technical leadership roles. This program is one method for targeting and encouraging these potential leaders, notes Jackson. He says, "Our hope is that some substantial fraction of the winners will become leaders of the Laboratory sooner rather than later. For many, their time for leadership will come faster than they expect it, and we need to prepare them for it."

—Rose Hansen

Key Words: additive manufacturing (AM), Accelerated Strategic Computing Initiative, algorithm, continuum model, denudation, distinguished member of the technical staff, Early- and Mid-Career Recognition (EMCR) Program, energetic material, fused-silica optic, groundwater, high foot, HMX, hydrodynamic growth radiography (HGR), hydrodynamic instability, laser chemical-vapor deposition, materials science, micromachining, multiphysics simulation, multiscale strength model, National Ignition Campaign (NIC), National Ignition Facility (NIF), optics damage, ParFlow, platform, pore collapse, selective laser melting (SLM), Suite of Nonlinear and Differential/Algebraic Equation Solvers (SUNDIALS), tantalum, time integrator, vanadium.

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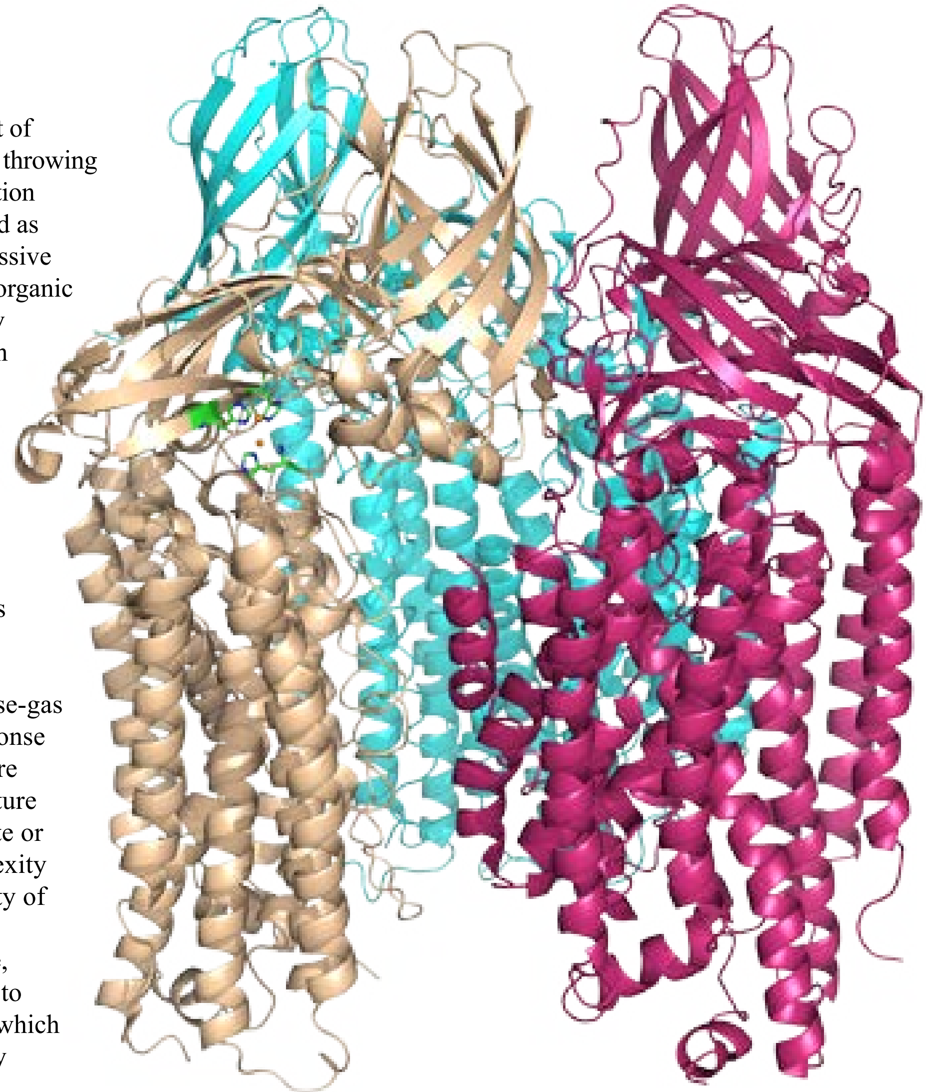
Mimicking Mother Nature to Mitigate Climate Change

ALTHOUGH carbon dioxide shoulders the majority of climate change blame, methane is the second most prevalent greenhouse gas. In addition, methane is 25 times more effective at trapping heat than carbon dioxide. This heat contributes significantly to Earth's changing climate, which can influence shifts in economic and agricultural trends and promote erratic weather patterns. (See *S&TR,* June 2012, pp. 4–12.) To help reduce methane emissions, Livermore scientists Sarah Baker, Joshuah Stolaroff, and their research team are developing an efficient way to convert methane to methanol—a liquid that has a wide range of applications.

Methane is emitted by wetlands, thawing permafrost, and grass-eating animals, and is broken down by soil microorganisms

Scientist Jennifer Knipe holds an additively manufactured donut-shaped hydrogel that is being developed to trap methane for conversion to methanol. (Photo by Maren Hunsberger.)



Particulate methane monooxygenase (pMMO) is an enzyme that methane-consuming bacteria called methanotrophs use to metabolize methane into methanol. Livermore researchers are focusing on pMMO as part of a scheme to trap methane as it is emitted from landfills and convert it to methanol. (Rendering by Edmond Lau.)

and atmospheric chemical reactions. Today, over 60 percent of the methane in the atmosphere results from human activity, throwing methane's natural cycle out of equilibrium. The decomposition of human-generated trash, for instance, is often overlooked as a source of greenhouse gases, yet this process releases massive quantities of methane through the degradation of volatile organic compounds and microbial action. Localized and stationary sources of methane such as landfills, natural gas extraction sites, and areas of rapidly thawing permafrost are the emission sources Baker's team is targeting with its innovative methane-conversion materials.

Nature Inspires Better Design

Traditionally, most landfill methane is emitted into the atmosphere or is "flared off"—burned for energy in a process that releases carbon dioxide. "Obviously, this is not an effective solution to the climate change problem," comments Baker. More recently, several government agencies have recognized landfill emissions as greenhouse-gas sources that can be easily identified and reduced. In response to increased political pressure, some large landfill sites are building methane-recapture plants. These operations capture emissions and convert them into energy that is used onsite or sold to outside companies. However, the cost and complexity of these systems have limited their adoption for a majority of landfills and natural gas extraction sites.

When considering options for creating a less expensive, more feasible methane mitigation approach, Baker turned to nature for inspiration. "Converting methane to methanol, which is the liquid form of gaseous methane, requires less energy than purifying and condensing methane gas," she explains. "The liquid is also easier and more efficient to transport, and methanol can be used in manufacturing and as fuel." However, no commercially viable small-scale chemical methods exist to convert methane to liquid fuel. The most mature technique, called the Fischer–Tropsch process, requires many complicated steps, making it inefficient and costly. Other methods use traditional stirred-tank bioreactors, which are slow and energy intensive—the process occurs in batches, after which all equipment must be cleaned and all organic substances separated out for reuse.

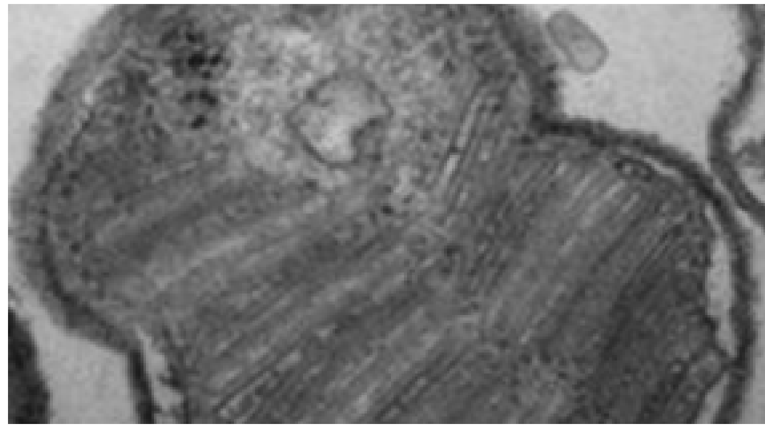
To make a smaller scale process more commercially viable, the research team looked to bacteria. "We see methanotrophs—bacteria that consume methane as their energy source and turn it into methanol—performing exactly what we want to do," notes Baker. "They know how to perform this conversion, so let's learn from them."

A Printable Structure

Methanotroph contain an enzyme called particulate methane monooxygenase (pMMO), which the organism uses to convert methane to methanol. This enzyme is embedded in folded lipid membranes that increase the surface area exposed to methane gas. Because pMMO is stored in a cell membrane, it is easy to extract and use. A partner research team at Northwestern University provided the pMMO for the Laboratory's experiments.

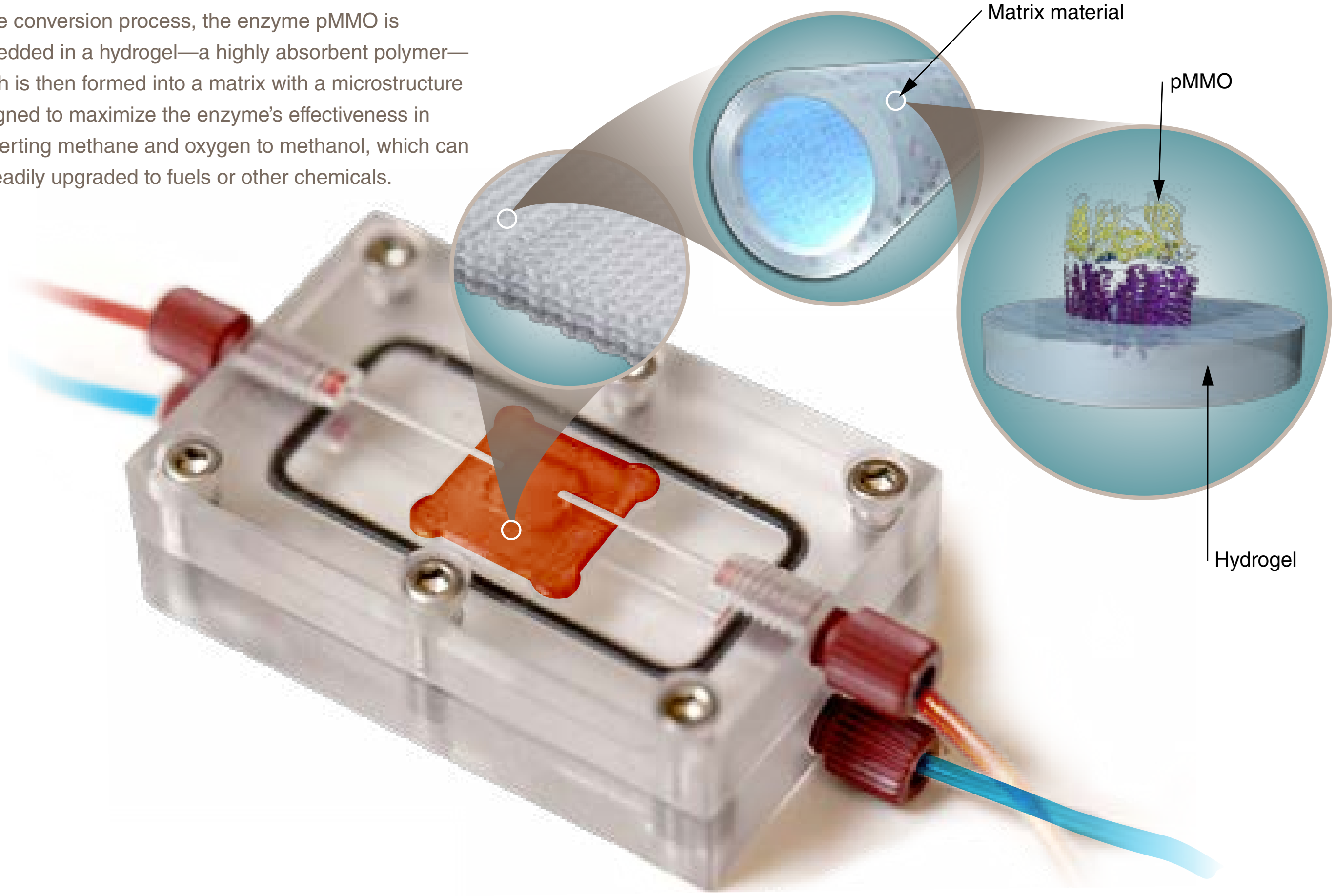
"Once we decided on this method of conversion," explains Baker, "the next step was to identify a more efficient way of introducing methane to the enzyme." Instead of forcing the gas into an enzyme-containing liquid, similar to the process used in conventional stirred-tank bioreactors, the team embedded pMMO in a hydrogel—a highly absorbent polymer made mostly of water—allowing them to increase the contact area between the enzyme and methane. Embedding pMMO in a printable hydrogel allows the team to mimic the bacteria's structure and also presents the possibility of using additive manufacturing to create the materials.

Jennifer Knipe, a postdoctoral researcher at Livermore and an expert in hydrogel formulation, was charged with finding the optimum hydrogel structure for methane–enzyme interaction.



The methanotropic bacterium *Methylococcus capsulatus* (Bath strain) provides Baker and her team with a source of pMMO to use in their methane capture and conversion approach.

In the conversion process, the enzyme pMMO is embedded in a hydrogel—a highly absorbent polymer—which is then formed into a matrix with a microstructure designed to maximize the enzyme's effectiveness in converting methane and oxygen to methanol, which can be readily upgraded to fuels or other chemicals.



"The consistency of the hydrogel polymer we're using, called polyethylene glycol, is very similar to a brittle contact lens," says Knipe. "We've been studying the literature on fluid–gas exchange in contact lenses to better design our polymer. The problem is that the hydrogel on its own behaves a bit like jello in that it can't be disturbed too much or it will fracture—so we tested plastic matrices that would act as scaffolding to give it more strength and structure."

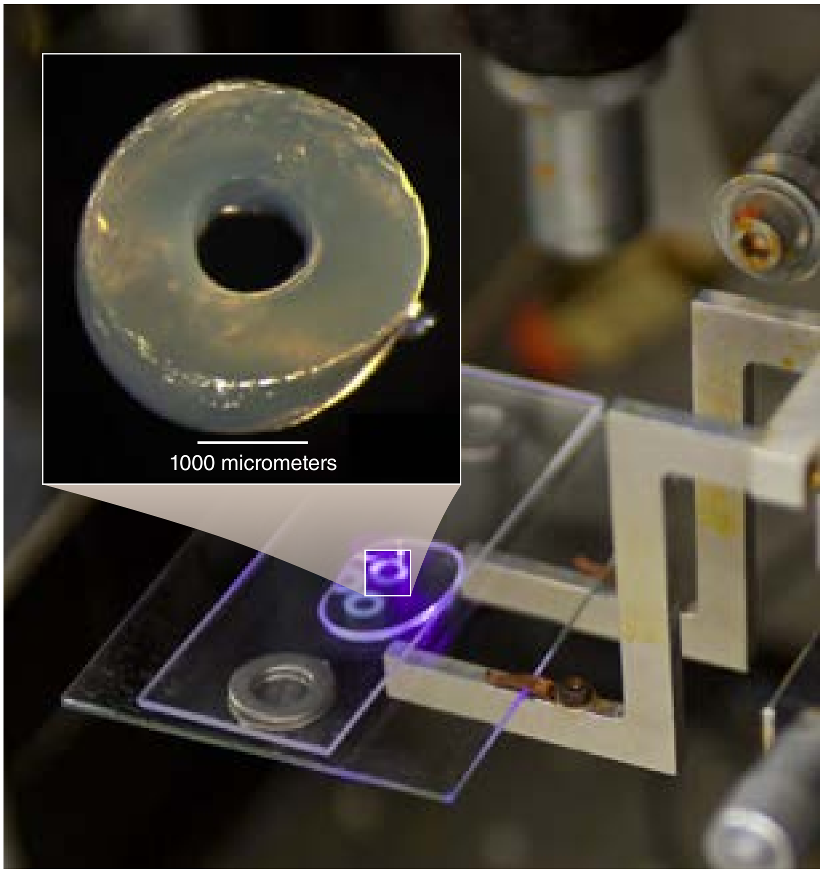
The team tested several structural designs for the matrix and found that a silicone mesh structure was effective but only when very thin. The methane–enzyme interaction is limited by diffusion and takes place within a few micrometers of the mesh's outside edge. The team also tested a hydrogel polymer without a matrix. Through their experiments, the team found that by making the polymer donut shaped, they could maximize its surface area and therefore increase methane conversion. "We're working on incorporating a silicone component into the donut-shaped polymer to keep it structurally sound," says Knipe. "The exciting part is that we're applying additive manufacturing to print the silicone matrices and the hydrogel quickly and simply, which could make this approach viable on a large scale."

The Future of Methane Conversion

Baker's team has already presented its findings on methane-to-methanol conversion at scientific conferences, and they plan to test other hydrogel polymers to determine whether any are less expensive and at least as effective as polyethylene glycol. Baker adds, "We also need to find an alternative to our cofactor," referring to an "assistant" molecule required for the enzyme to function properly in a laboratory setting. When the pMMO is removed from inside the bacteria, the molecules that naturally assist its function no longer surround it. The team used a reduced form of nicotinamide adenine dinucleotide (known as NADH) for their experiments, which is an expensive substance. Knipe notes, "Another limiting element is the enzyme itself. It breaks down after a certain period of time, and then we have to add a fresh batch. We're looking into why this breakdown occurs so we can preserve the enzyme's lifespan."

Although the process still needs to be refined and scaled up, the researchers are optimistic about its possible applications. "An efficient process could give industry more tools and incentives to reduce methane emissions," states Baker. The team will continue to draw inspiration from nature in its pursuit of mitigating one of the world's most potent greenhouse gases.

—Maren Hunsberger



A donut-shaped hydrogel is the most effective structure for trapping methane. Additive manufacturing can be used to fabricate the shaped hydrogel. The structure is then cured using ultraviolet light. (Photo by Maren Hunsberger.)

Key Words: additive manufacturing, biochemistry, bioreactor, climate change, Environmental Protection Agency, enzyme, greenhouse gas, landfill, materials science, methane, methane catalysis, methanogenesis, methanol, methanotroph, natural gas, particulate methane monooxygenase (pMMO), polymer.

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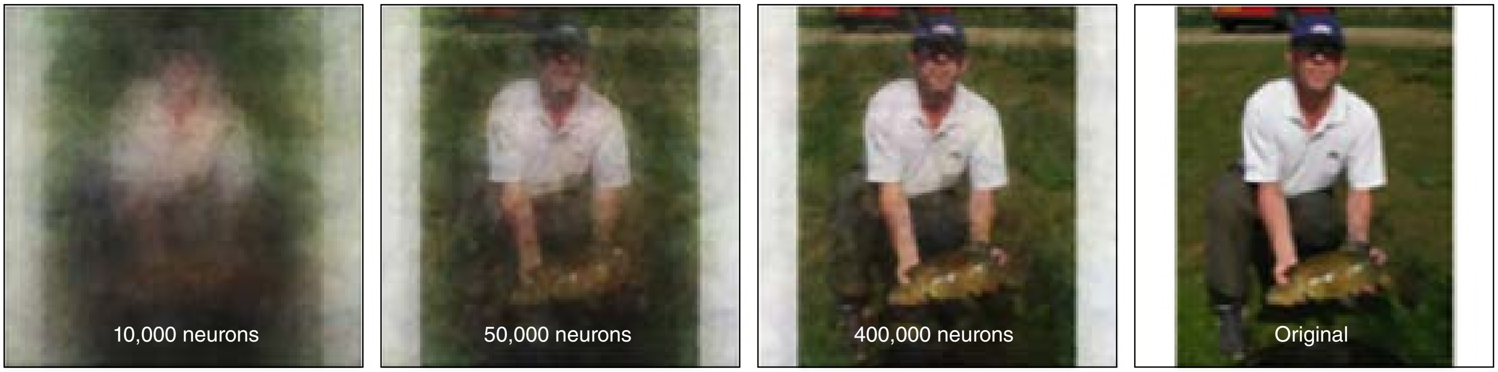
Deep Neural Networks Bring Patterns into Focus

WITH each new version, the typical smartphone's talking digital assistant seems to get better at recognizing spoken language and responding appropriately to requests such as "Make a noon reservation the nearest Thai restaurant." Yet the same digital assistant would be flummoxed if asked to parse the content of a digital photo of, say, a person throwing a ball to a dog on a grass field in a park. The key to such a capability is the ability to recognize patterns, something that humans do quite well, but is still relatively primitive in the computing world. This capability is also greatly needed in applications such as analyzing satellite photographs, where data collection is far outpacing the ability of human analysts to process the data.

The rapid rise of a branch of machine learning known as deep learning is about to change computing capability. Deep learning algorithms are now being used to train a new generation of artificial neural networks (ANNs) that potentially offer game-changing performance. After years of relatively little attention, the ANN field has recently exploded, and universities and major technology companies such as IBM, Google, Facebook, Baidu, and Apple are investing heavily. A Livermore deep learning research



The improving image quality from left to right shows how well a single-layer autoencoder trained with the Livermore Big Artificial Neural Network (LBANN) toolkit is able to reconstruct a training image when using hidden layers consisting of 10,000, 50,000, and 400,000 neurons.

team led by machine learning researcher Barry Chen is working to advance deep learning capabilities and apply them to Livermore's national security missions and basic-science research.

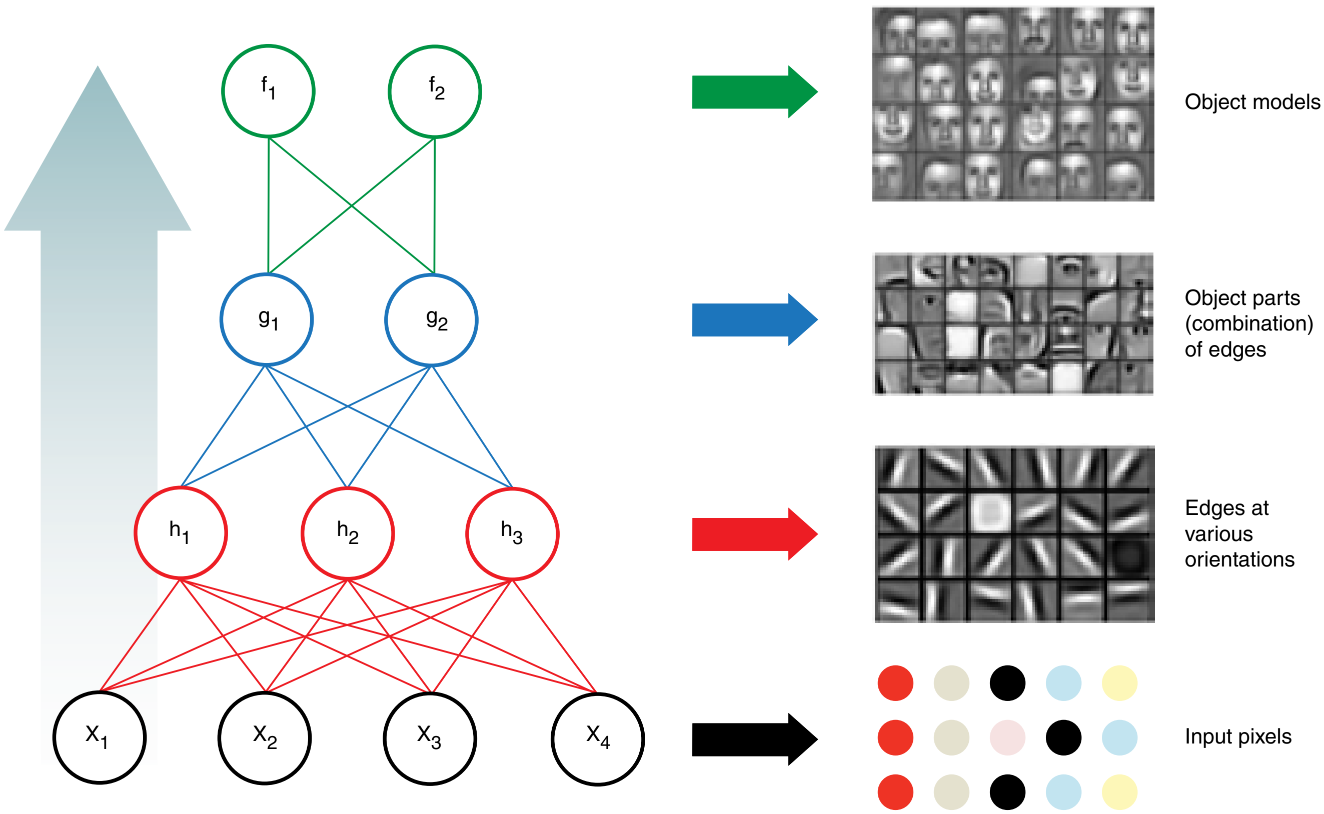
The Livermore team recently developed the Livermore Brain—the world's largest neural network based on unsupervised learning with image data—along with the accompanying software for training massive neural networks. Together, the toolkit is called the Livermore Big Artificial Neural Network (LBANN). In partnership with Yahoo!, Flickr, and the International Computing Science Institute, they also developed and released a massive publicly accessible multimedia data set for pattern recognition and artificial intelligence research called the Yahoo Flickr Creative Commons 100 Million (YFCC100M). Responding to the need for a large, publicly available data set for research, YFCC100M is a "training" database of 100 million images and videos.

Inspired by Living Systems

The computing architecture of the Livermore Brain and other ANNs is inspired by the nervous system of living beings. The exquisitely filigreed mesh of cells called neurons that forms our nervous system and brain processes inputs from the senses and allows us to recognize objects, understand how our environment is changing, and respond accordingly, among myriad other tasks. The computational building block of an ANN is also called a neuron or unit. Groups of units are connected linearly to form layers, with each unit in an input layer connected to each unit in the next layer, and so on through to the final output layer. The layers between input and output are called hidden layers. The deep ANN's predecessor, the shallow ANN, consisted of a few hidden layers, typically one or two. State-of-the-art deep ANNs have many more hidden layers, typically between 15 and 30, but as many as 152. "The deep neural network is one of the technological innovations that allows us to solve problems that shallow networks could not," explains Chen. "The combination of high-performance computing (HPC) power, massive data, and deep neural networks is what makes possible human-performance-level image recognition with machines."

In the Livermore Brain, a unit is a block of software code. Each unit in the ANN possesses a set of weights (numbers between zero and one) that are "learned" through an optimization procedure to minimize the errors that the ANN makes on a training data set (such as the YFCC100M) consisting of input and desired output target pairs. As data are fed through the ANN during the training process, the resulting output is compared to the desired target. Errors between the ANN output and the target are "back propagated" through the network, assigning blame to the weights responsible for the error. As training proceeds, the weights change and converge toward an optimal configuration for minimizing the ANN's overall error. Feed millions of digitized images through a sufficiently fast and powerful ANN, and these weights begin to represent the underlying common features within the image, forming what Chen calls an "abstract concept space."

The process of training the Livermore Brain relies on an architectural element called the autoencoder, whose training targets are simply the original inputs themselves. That is, the ANN outputs a reconstructed version of the input image. Repeated millions of times with millions of images, this training allows the ANN to get better at reconstructing input. One set of neurons "learns" to recognize edges—boundaries—while the next may register shapes and shadows—the elements of faces, for example, eventually arriving at a set of elements and their relationships that form the class of faces. In 2012, a deep-learning ANN, the Google Brain, with one billion trainable weights running on 1,000 machines, "learned" to distinguish images of faces and cats by training on 10 million 200-by-200-pixel images sampled from YouTube—remarkably, without having labeled training data explicitly designating the category of each image. Researchers at Stanford University replicated the feat, training an ANN on the same number of images using just



A deep learning neural network such as the Livermore Brain recognizes images through a hierarchy of layers composed of units represented by circles, with each unit connected to units in the layer above it. Starting with (black) input, the network first (red) recognizes the most basic components, such as edges, then (blue) parts containing multiple components, and finally (green) the object itself. (Right-hand images courtesy of Honglak Lee.)

three HPC nodes—CPUs assisted by graphics processing units (GPUs)—thanks to more efficient programming exploiting the massive parallelization afforded by GPUs.

Learning Is Better When Unsupervised

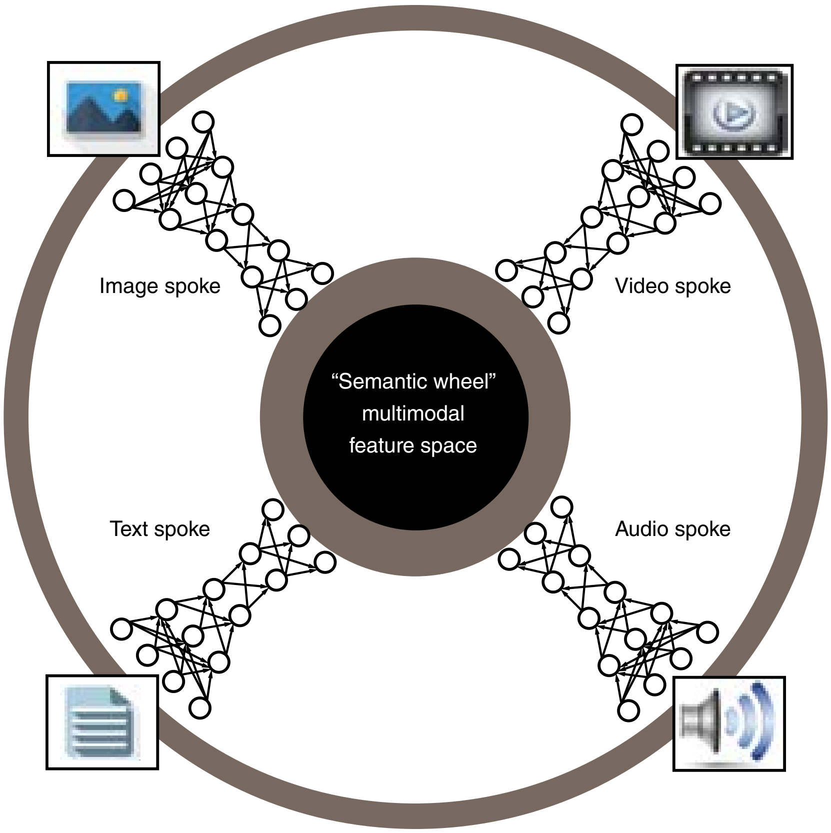
The ability to perform unsupervised learning is what gives the Livermore Brain and others like it so much applicability. "In supervised learning, you have to label the data, which is time consuming and labor intensive," says the Laboratory's Brian Van Essen. "Unsupervised learning allows the neural network to take advantage of massive amounts of unlabeled data to find the description of the data it needs to do a good reconstruction on its own. In other words, the network does its own feature extraction."

Incorporating Stanford code, the Livermore Brain represents the next big leap—the largest unsupervised learning–based deep neural network to date trained on image data. With 15 times as many parameters as Google Brain running on 98 nodes of Livermore's Edge supercomputer, the Livermore Brain has nine layers and 15 billion trainable parameters. Using the YFCC100M database's 99.2 million 300-by-300-pixel images, the network "learned" how to distinguish among a variety of image classes, including city skylines, buildings, aircraft, towers, and text, all without labeled training images.

Van Essen's group is working to further improve the speed and efficiency of LBANN by developing techniques to maximize each node's utilization—so that the network's computing resources are used as fully as possible—while minimizing communication between the nodes, which slows down the network.

Real Data from the Operating Room

Researchers in Chen's group have embarked on several projects funded by the Laboratory Directed Research and Development Program to improve the performance of and develop applications for LBANN. A collaboration between Lawrence Livermore and the University of California at San Francisco (UCSF) is working to apply electrocorticographic (ECoG) data from human brains to neural networks. The ECoG data, collected from epilepsy patients



With the help of high-performance computers and the LBANN, Livermore researchers are developing the "semantic wheel" concept. It will will map multimodal data—images, audio, text, and video—into a feature space that associates objects within similar data classes, such as words, images, and video all related to buildings.

awaiting brain surgery to treat their condition, are used by surgeons to determine the areas of a patient's brain on which to operate. Electrodes are implanted in their brains, and their activities in their hospital rooms are recorded on video cameras. The ECoG data thus provide a record of which areas of the brain are stimulated when the patient's body engages in activities such as moving arms and hands to eat or using muscles in the legs and elsewhere to shift position in bed.

In this project, Livermore researchers Kofi Boakye, Alan Kaplan, and their UCSF colleagues will feed video of patients through deep neural networks and attempt to correlate brain activity patterns from ECoG data with these specific movements. "We're interested both in what's going on in the brain and how we can use the techniques we develop to improve computer vision and analysis," explains Boakye. "We're going to cast as broad a net as possible and use the project to help us identify applications of interest to a variety of users beyond the medical community."

Things to Come—the Semantic Wheel

"The broader vision of Livermore's neural network research," explains Chen, "is to fuse different types of data—images, audio, video, and text—into a shared feature space where data of related concepts are proximal. Our framework for doing this is called the semantic wheel. The spokes in the wheel are deep neural networks responsible for learning atomistic representations of individual data modalities. An alternating optimization procedure merges the output of individual spokes, resulting in a shared feature space that will enable the association of elements within images, audio, and video, with text descriptions and vice versa."

The semantic wheel approach could soon be able to find a car or a face—or a person throwing a ball to a dog on a grass field in a park—within thousands of images, or find relationships among variables in millions of data points generated by a high-energy physics experiment, for instance. Livermore's research is leading the way in this approach through the merging of HPC, advanced deep learning architectures, and the largest image data set ever published to create powerful new tools for basic science research and national security applications.

—Allan Chen

Key words: artificial intelligence, artificial neural network (ANN), Edge supercomputer, electrocorticography (ECoG), epilepsy, high-performance computing (HPC), Laboratory Directed Research and Development Program, Livermore Big Artificial Neural Network (LBANN), Livermore Brain, machine learning, neuron, pattern recognition, semantic wheel, Yahoo Flickr Creative Commons 100 Million (YFCC100M).

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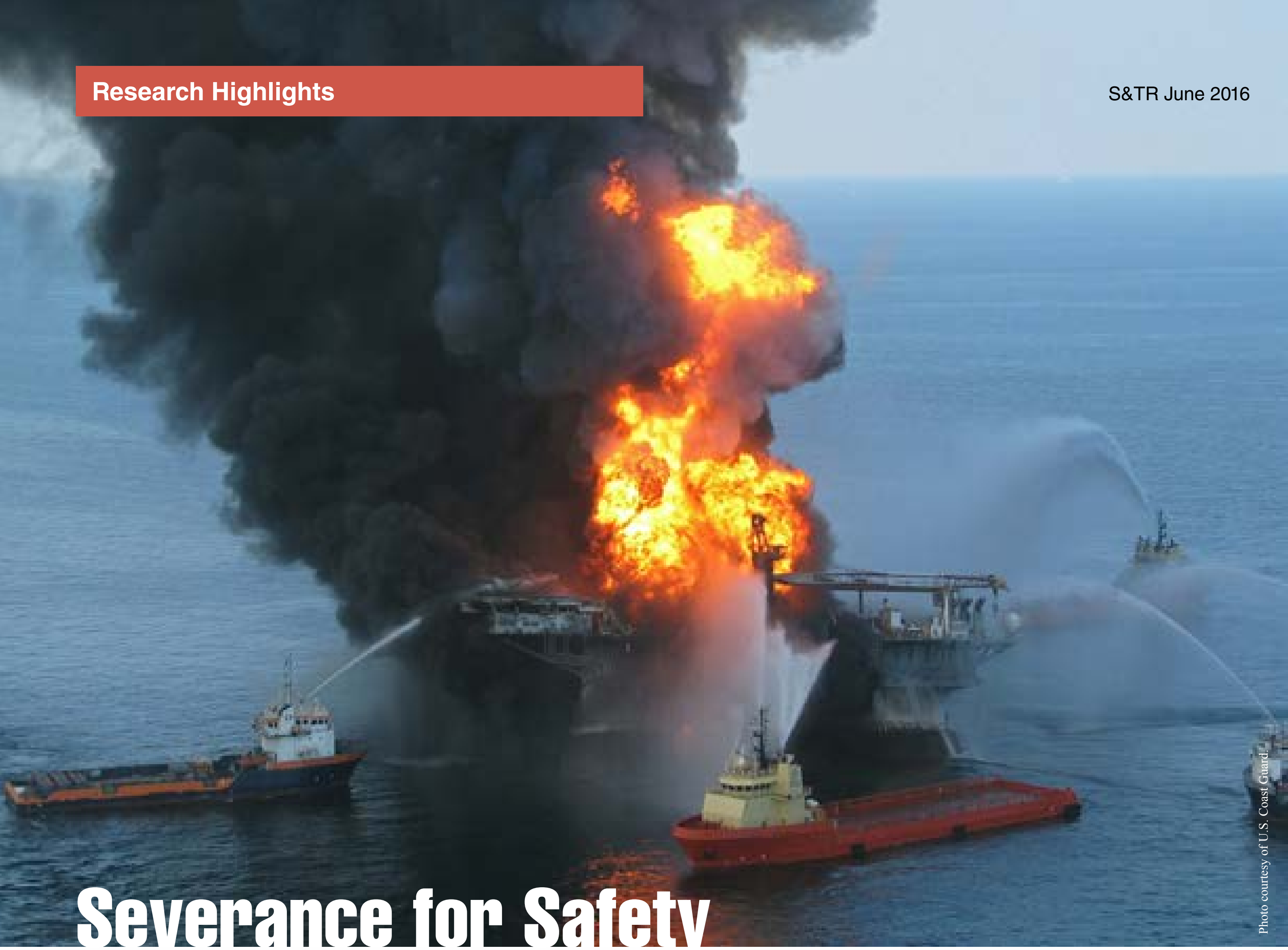


Photo courtesy of U.S. Coast Guard.

Severance for Safety

Preventing Subsea Oil-Related Disasters

THE 2010 Deepwater Horizon oil spill was the largest marine oil spill in U.S. history, releasing millions of barrels of oil into the Gulf of Mexico. The incident, which claimed the lives of 11 crew members, caused catastrophic damage to the Gulf of Mexico and surrounding environments. The oil platform's blowout preventer was supposed to sever the drill pipe and stop the flow of oil and gas, but it malfunctioned, allowing oil and gas to flow unimpeded into the Gulf. After the Deepwater Horizon event, Livermore researchers evaluated possible solutions to the problem (see *S&TR*, March 2011, pp. 10–17) and considered options for how to prevent such an event in the future.

Shell International Exploration and Production Inc. (SIEP) decided on an explosives-based emergency severance tool that could be activated upon failure of the blowout preventer. SIEP approached the Laboratory to suggest a specific technological solution. A team of Livermore researchers applied advanced simulation capabilities and expertise in high explosives stemming from stockpile stewardship work to develop an initial design for a robust emergency severance tool. "The emergency severance tool serves as a fail-safe device," explains principal investigator Dennis Baum. "It's comparable to having a fire extinguisher in a home. The home is not expected to burn, but the fire extinguisher is there to fight any fire that may occur."

The novel technology that Baum's team created uses an array of six shaped charges that simultaneously detonate on command to sever the connection between the blowout preventer and the surface drilling rig, called the marine riser system. Placed just above the blowout preventer, the emergency severance tool allows the rig to motor away from the well, potentially saving lives and preventing rig damage. Making oil-drilling technology more safe and reliable contributes to Lawrence Livermore's energy security mission.

Reliability and Simplicity

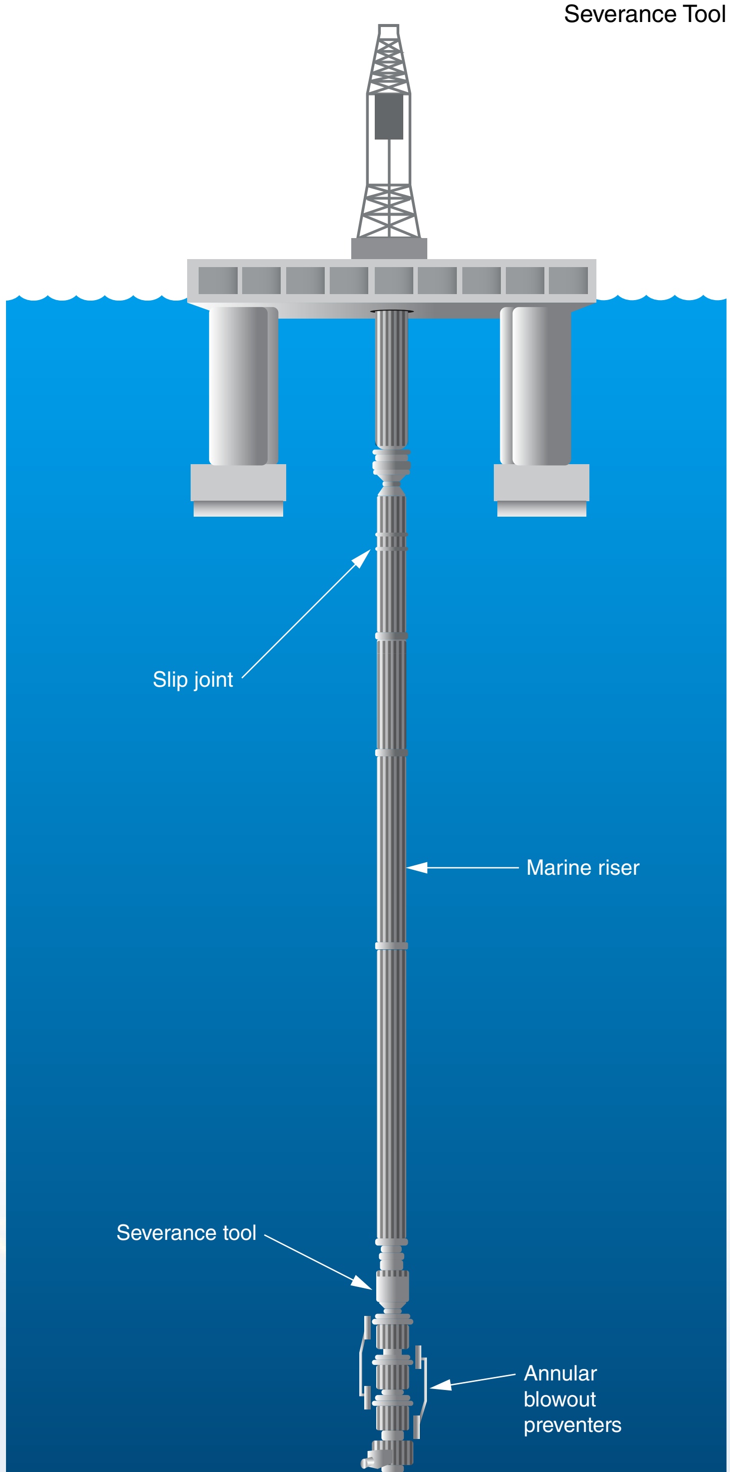
The blowout preventer is equipped with multiple blind shear rams—hydraulic devices with twin cutting blades that sever the drill pipe and block the flow of oil and gas escaping from the well. In the Deepwater Horizon incident, the steel drill pipe buckled under pressure, stopping the blowout preventer from fully severing the pipe and sealing the well. Learning from this event, SIEP sought a backup technology that would mitigate the risk of future catastrophic spills.

The backup emergency severance tool had to be extremely reliable, able to withstand remote deep-water conditions, maintain functionality for 12 months (the duration of a drilling operation), and meet strict size, geometry, and weight limitations. Livermore's design was chosen over those proffered by other institutions. "Similar to a nuclear weapon, this system needs to be very reliable," says Baum. "Its use of explosives puts it in Livermore's wheelhouse, where we can tap our vast experience with stockpile stewardship–focused projects."

Building on a long history of developing special-purpose explosive charges, the emergency severance tool design uses linear-shaped charges—blocks of high explosives in a simple, long, rectangular shape—which are commonly used for construction and demolition projects. Each 15-centimeter-long shaped charge has a copper-lined cavity running down one edge. The explosive is backed by a unique lighting (initiation) system and detonator, a device that converts an electrical pulse into a small detonation that initiates the high explosive. When propagating through the explosive, the detonation wave rapidly squeezes and collapses the copper liner, causing a copper sheet (or jet) to shoot out at very high speed, slicing through the drill pipe. Other charge shapes, such as cones or spheres, are routinely used to penetrate heavy material, but a linear sheet, which acts like a blade, proved most suitable to cutting the steel drill pipes. "Linear-shaped charge arrays are simple, effective, and efficient," says Baum. "The design developed by our team must operate in a complex, multifaceted environment to accomplish something never done before."

Subsea Challenges

The Livermore team had to address conflicting design requirements to ensure severance. The charges, each containing a little more than 2 kilograms of explosives, are uniformly spaced and face radially inward within the steel mandrel, whose bore matches the marine riser system. This mandrel mimics the inner chamber (pressurized at 1 atmosphere) that will house the charges subsea. All charges must detonate simultaneously to generate maximum effectiveness and achieve full severance. The copper jets must penetrate four regions defined by the 7.6-centimeter-thick steel mandrel, the fluid within the marine riser, the steel pipe—commonly referred to as the drill collar—and any fluid inside the drill collar. The power of each jet must be sufficient to



The Livermore-designed emergency severance tool is positioned on top of the blowout preventer. The tool would be activated if the blowout preventer were to malfunction, as happened during the Deepwater Horizon event.

account for variation that can degrade the force of the jets as they penetrate toward and through the target.

Penetration varies with distance from the target. Inside the riser, the position of the drill collar fluctuates during the drilling operation. The steel pipe is not always centered, and its exact location upon system initiation may be unknown. In a worst-case scenario, the drill collar could be fully eccentric, located farther from some charges than others. Lack of centralization is purported to have contributed to the Deepwater Horizon event. In the proposed emergency severence tool, the drill collar is not subjected to equal destructive force from each charge. The emergency severence tool housing must remain intact while isolating the surrounding environment and equipment from shock waves, debris, and byproducts of the explosion. After severance, the oil rig, equipped with thrusters simlar to a ship, can disconnect and maneuver away from the well. Livermore design physicist Kirsten Howley says, "I am encouraged that SIEP has been exploring these technologies to protect the safety of their crew."

In Agreement: Testing and Simulations

Livermore's emergency severance tool design was validated through a series of five experiments and numerous simulations. The first two experiments, conducted at the Laboratory's High Explosives Applications Facility, validated the performance of the lighting system to ensure synchronization of the six separate explosions. The next two experiments, performed at Site 300, tested the behavior of the shaped charges in air—to establish a baseline for charge and jet behavior—and in drilling mud, to allow for subsea conditions. To study the basic behavior of jet formation and performance, the first of these tests was conducted with the jet propagating through air before impacting the target. The bladelike jet of copper created an elongated crater in the target, with complete penetration occurring near the center of the jet. The second test examined jet erosion by detonating the charges in a tank filled with drilling mud. Radiographic data were collected during these experiments so that the results could be compared with simulations of jet speed and configuration. Livermore researchers found that both tests accurately reproduced details of the jet's structure and performance as predicted by the simulations.

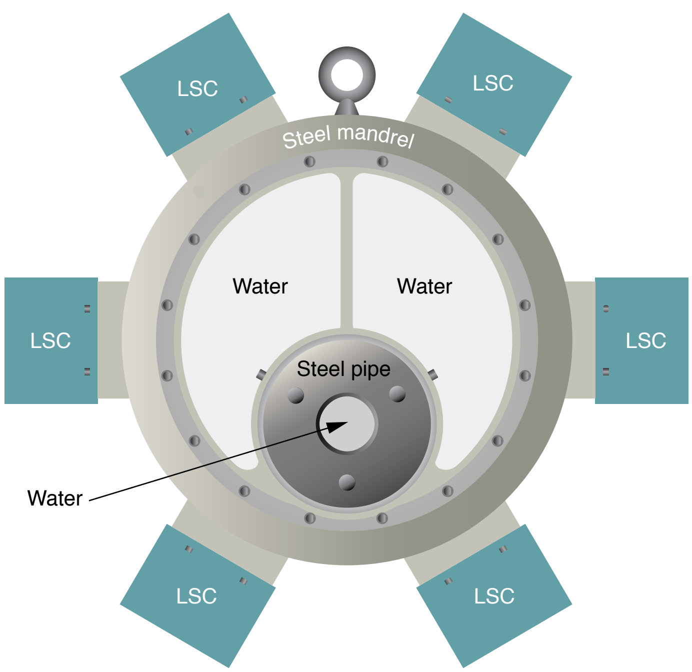
The final Site 300 experiment examined the behavior of the complete array and demonstrated the array design's potential. Using 72 time-of-arrival flashers (12 in each charge), six time-of-arrival films, and seven underwater optical fibers to measure the jet time of arrival, among other diagnostics, the team recorded and closely analyzed array behavior. As predicted by pre-shot simulations, the experiment achieved 90 percent severance.

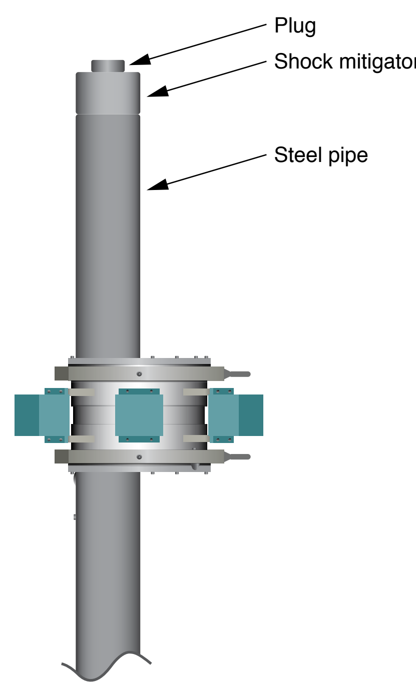
The ability to accurately simulate near severance is no easy feat. Through these models, the team has increased confidence in its simulation capabilities to further improve the technology. "I am confident our team is only a design tweak away from making our emergency severance tool fully functional," declares Baum. "If we replace some of the components with better engineered materials and tailor some design details as indicated by our simulations, I expect we will achieve success."

Going the Distance

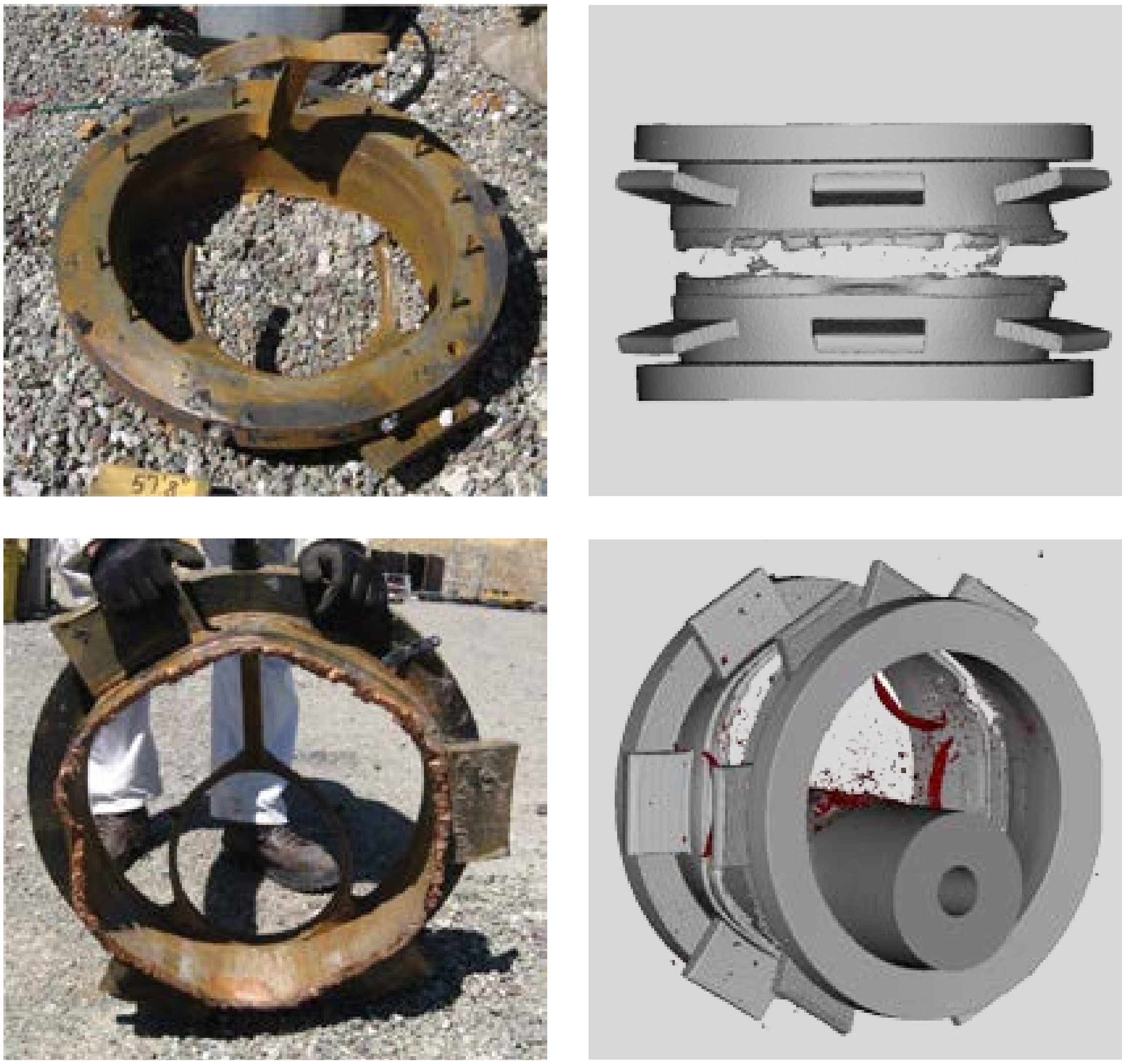
Livermore hydrodyanic simulations also agreed with the experimental results. Going forward, the Livermore team and SIEP can use these models to modify their experimental design, knowing that they would get similar outcomes experimentally.

The emergency severance tool that Livermore designed for Shell International Exploration and Production Inc. features an array of six linear-shaped charges (LSCs), which will sever the thick steel pipe in the event of a malfunctioning blowout preventer.





Experiment Simulation



The results of (left) experiments conducted at Site 300 with the full array of explosives agreed well with (right) simulations of the array's severance function. The LSCs detonated and severed the steel mandrel as expected. These results gave the researchers confidence that their array design will function as intended in the field.

Relying on simulations to guide future enhancements cuts time and cost. "Simulations are most valuable for their predictive capability," explains Howley. "As a national laboratory, we focus on stockpile stewardship computational tools supported by validating experiments. Therefore, we rely heavily on our computing capabilities to show that we can model energetic and complex events."

In the future, the researchers will use the simulations to identify design changes that could optimize the current emergency severance tool design to achieve a robust 100 percent severance. They also plan to model and test alternate scenarios, such as different drill pipe sizes and locations within the marine riser system, to understand performance sensitivity to real-world variations in drilling operations. In addition, the team will examine different amounts and distributions of high explosives.

As with so many Livermore projects, this effort marries simulation and experiment to determine design parameters more quickly, efficiently, and inexpensively. Using these capabilities, Baum and his team created a novel device with the potential to transform the safety of oil drilling operations in the interest of saving lives, protecting the environment, and improving energy security.

—Lanie L. Rivera

Key Words: blowout preventer, Deepwater Horizon, emergency severance tool, high explosive, High Explosives Applications Facility, linear-shaped charge, oil rig, oil well, Shell International Exploration and Production Inc., Site 300, stockpile stewardship.

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Patents and Awards

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-digit number in the search box at the U.S. Patent and Trademark Office's website (http://www.uspto.gov).

Patents

Monodisperse Microdroplet Generation and Stopping without Coalescence
Neil Reginald Beer
U.S. Patent 9,266,107 B2
February 23, 2016

Battery Management System with Distributed Wireless Sensors
Joseph C. Farmer
U.S. Patent 9,267,993 B2
February 23, 2016

Electrode Geometry for Electrostatic Generators and Motors
Richard F. Post
U.S. Patent 9,270,203 B2
February 23, 2016

Technique for Enhancing the Power Output of an Electrostatic Generator Employing Parametric Resonance
Richard F. Post
U.S. Patent 9,270,204 B2
February 23, 2016

Awards

The Astrophysics Division of the **American Astronomical Society** has selected Livermore researcher **Peter Beiersdorfer** as recipient of the **2016 Laboratory Astrophysics Prize**. This honor is given each year to an individual who has made significant contributions to laboratory astrophysics over an extended period of time. The society cited Beiersdorfer for his numerous contributions to the study of astronomical environments at extreme-ultraviolet and x-ray wavelengths.

Beiersdorfer pioneered techniques to reproduce conditions on comets and in the Sun's atmosphere, interstellar space, and the centers of galaxies. A major focus of his research is atomic and molecular diagnostics as revealed by x-ray spectra. Beiersdorfer's studies of emissions from the inner electron shells of iron, oxygen, neon, silicon, and sulfur are widely used today to interpret the physical conditions in astronomical environments. His work on x-ray emission from charge exchange revealed the importance of this process in cometary atmospheres. Beiersdorfer has carried out laboratory astrophysics work at the Livermore electron beam ion trap facility since 1991 and conducted laboratory astrophysics measurements at U.S. magnetic fusion facilities, most notably the National Spherical Torus Experiment at Princeton. With his collaborators, Beiersdorfer has published more than 500 scientific papers, more than 50 of which have appeared in *Astrophysical Journal*, *Science*, or *Nature*.

Laboratory materials scientist **Vince Lordi** was selected to receive a 2016 **Young Leaders Professional Development Award** from the Functional Materials Division of **The Minerals, Metals, and Materials Society** (TMS). This award was created to enhance the professional development of dynamic young people from TMS' five technical divisions by helping them participate in society activities, network with TMS leaders and prominent members, and otherwise gain the experience and insight needed to become future leaders in the society's administration. The award was formally presented on February 15, 2016, at the 145th TMS Annual Meeting in Nashville, Tennessee.

Kevin Fournier, **Steve Compton**, and **Bill Dunlop** were part of a team recognized with the **2015 Alan Berman Publication Award** for a paper reporting on shock-wave experiments. The paper, "High-power laser and explosive driven shock wave characterization in solids using fiber optic probes," was presented at the International Society for Optics and Photonics' 24th International Conference on Optical Fiber Sensors and reported on studies of shock wave transmission and propagation in solid media using fiber optic pressure and velocity probes. The work was sponsored by the Defense Threat Reduction Agency, and Fournier et al. were coauthors on the paper along with collaborators from the Naval Research Laboratory (NRL) and SRI International. The Berman Award was established by Alan Berman, a past director of the NRL, to recognize the best published technical writing in each NRL scientific division.

Abstract

A Salute to Promising Technical Staff

In 2015, Lawrence Livermore implemented the Early- and Mid-Career Recognition (EMCR) Program to recognize and reward outstanding scientists and engineers who earned their highest university degree between 5 and 20 years ago. Winners receive a cash award and one year of funding for up to 20 percent of their time to pursue research activities in their area of interest. Five of the 15 EMCR awardees selected in the program's inaugural year include a mathematician, three physicists, and a materials scientist. Kumar Raman designs and simulates fusion and weapons experiments performed at the National Ignition Facility and other locations. Carol Woodward creates and applies algorithms that make simulations of complex physics processes run more efficiently. Nathan Barton models materials under extreme conditions, such as shocked explosives, to understand material strength and other properties. Manyalibo (Ibo) Matthews performs experiments to understand how laser-induced optical damage occurs and how to fix it, and applies these methods to applications such as additive manufacturing. Brian Pudliner develops physics codes for national security applications and supports code users. Their research spans a range of scientific areas, methods, and applications, and all these individuals have made notable contributions to Livermore's missions and to science.

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Detecting Radioactive Materials

Technology and training go together to improve searches for and responses to radiological sources.

Also in July/August

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- *An integrated multi-institutional computational, theoretical, and experimental effort improves scientists' understanding of dense plasmas.*

- *As part of an international team, Livermore scientists hunt for answers to mysteries of the neutrino using neutrinoless double beta decay.*