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

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.)

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, 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.

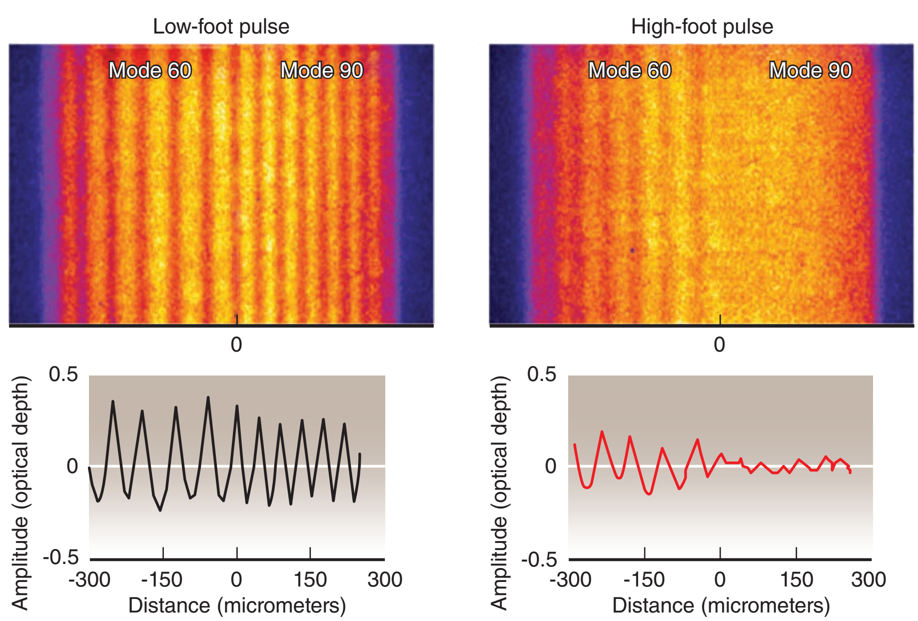
EMCR awardees selected in the program's inaugural year include Félicie Albert, Nathan Barton, Stefan Hau-Riege, John Heebner, Sergei Kucheyev, Felice Lightstone, Stephan MacLaren, Manyalibo (Ibo) Matthews, Miguel Morales-Silva, Jennifer Pett-Ridge, Brian Pudliner, Kumar Raman, Dawn Shaughnessy, Vanessa 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.

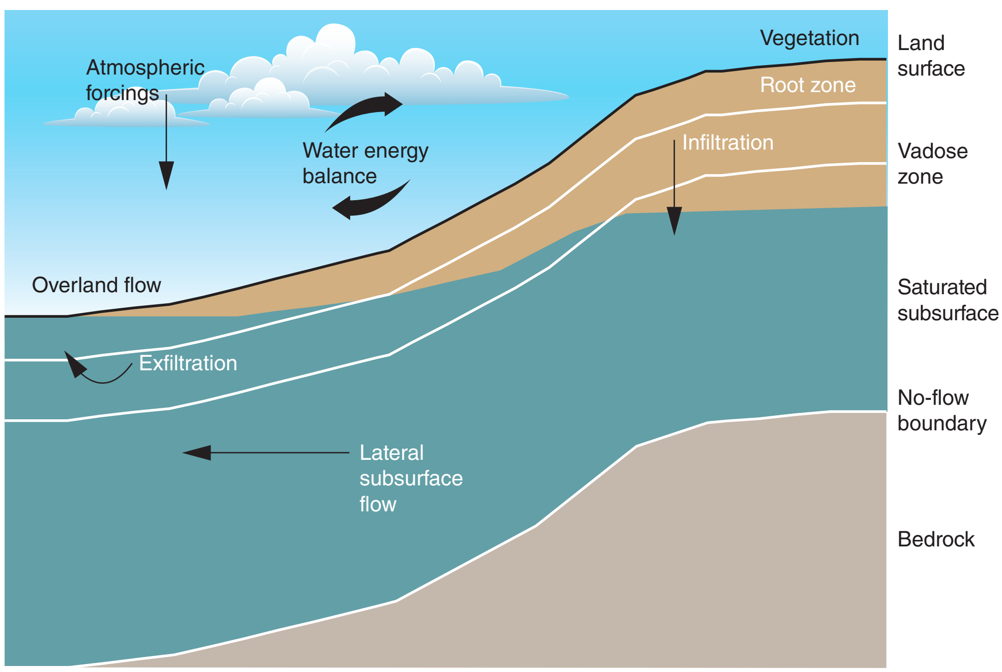
A career highlight for Raman was leading the design effort to develop a NIF radiography platform to measure the growth of Rayleigh–Taylor and Richtmyer–Meshkov hydrodynamic instabilities in fusion capsules. (See *S&TR*, June 2014, pp. 4–10.) Hydrodynamic growth radiography (HGR) experiments, which have 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."

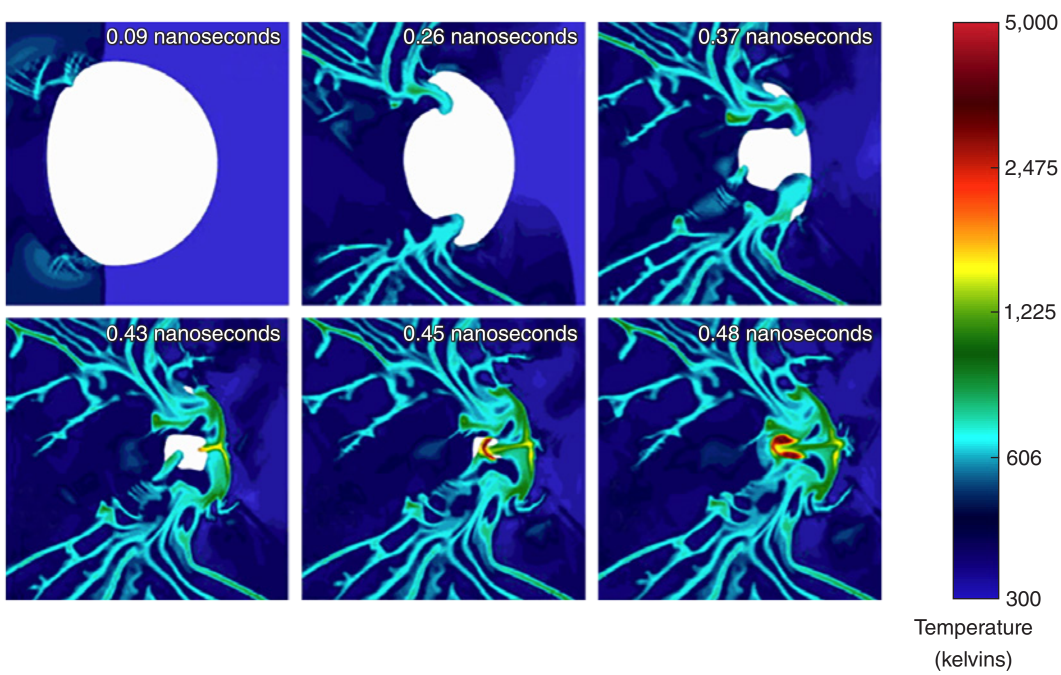
Woodward has continued to work with researchers such as Tompson and hydrologist Reed Maxwell at the Colorado School of Mines to enhance and apply ParFlow to various projects. By combining ParFlow with a land surface model, the team was able to efficiently model interactions between ground and surface 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.)

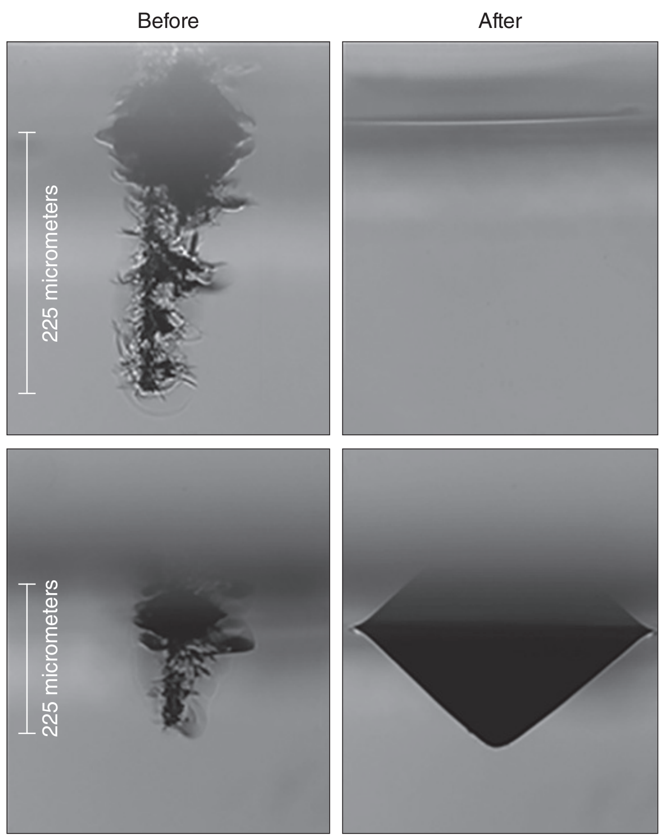
(millimeter and above) models, scientists can more accurately simulate the evolution of mechanical and chemical changes in materials. (See *S&TR*, December 2000, pp. 4–11; June 1999, pp. 22–25.) Barton's specialty is mesoscale continuum modeling. "Continuum is the scale at which we don't explicitly treat 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.

For further information contact Ken Jackson (925) 422-6053 (jackson8@llnl.gov).