Science & Technology REVIEW

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Advanced Surveillance Imagery

Also in this issue:

Simulating Biofuel Performance

Brighter Gamma-Ray Light Source

Energy Storage for the Grid

About the Cover

As the article beginning on p. 4 describes, Persistics software promptly processes, stores, and extracts meaning from data generated by modern overhead imagery taken from remotely piloted aircraft such as the Reaper and Predator. By finding, tracking, and monitoring people, vehicles, and events of interest on a continuous basis with wide-area video cameras, these aircraft provide persistent intelligence, surveillance, and reconnaissance to help the Department of Defense and other agencies monitor tens of square kilometers from the skies. (On the cover, a Predator drone photo, courtesy of the Department of Defense, is shown above an image of a possible surveillance target area.)

Cover design: Amy E. Henke

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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Speeding Up a Natural Mitigation Process

Livermore researcher Greg Rau conducted a series of laboratory-scale experiments to find out if a seawater–mineral carbonate (limestone) gas scrubber could effectively remove carbon dioxide (CO_2) from a power plant's flue stream. He then studied whether the resulting substance—dissolved calcium bicarbonate—could be stored in the ocean where it might also benefit marine life. Rau, who is also a a senior scientist with the Institute of Marine Sciences at the University of California at Santa Cruz, found that the scrubber removed up to 97 percent of CO_2 in a simulated flue gas stream, with a large fraction of the carbon ultimately converted to dissolved calcium bicarbonate.

When CO_2 is released into the atmosphere, the ocean passively takes up a significant fraction in a form that makes the ocean more acidic. Research shows that acidification is harmful to marine life, especially corals and shellfish. In contrast, the tested process would hydrate the CO_2 in power plant flue gas with water to produce a carbonic acid solution. This solution would react with limestone, neutralizing the CO_2 by converting it to calcium bicarbonate, which could then be released into the ocean. This process occurs naturally (carbonate weathering), but it is too inefficient and too slow-paced to be effective if the CO_2 were directly injected into the ocean.

"Our approach not only mitigates CO_2 but also potentially treats the effects of ocean acidification from atmospheric release," says Rau. "Further research at larger scales and in more realistic settings is needed to prove these dual benefits." The process would be most applicable for CO_2 mitigation at coastal, natural gas-fired power plants. The work, funded by the Energy Innovations Small Grant Program of the California Energy Commission and Lawrence Livermore, appeared online December 28, 2010, in *Environmental Science & Technology*.
Contact: Greg Rau (925) 423-7990 (rau4@llnl.gov).

Combating Antibiotic-Resistant Bacteria

A research team led by Paul Jackson has discovered a new way to combat antibiotic-resistant bacteria by turning the pathogen's own genes and processes against it. Despite the advances made to antibiotics over the years, the list of antibiotic-resistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli*, *Salmonella,* and *Campylobacter* is growing and becoming one of the world's most serious health concerns. Infections once routinely treatable have now become more difficult to combat and potentially more lethal.
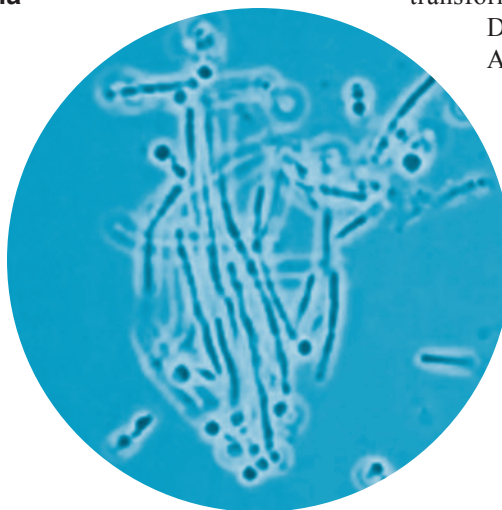
The researchers have taken a novel approach to fighting antibiotic-resistant bacteria by developing a new generation of antibiotics, based on a much deeper understanding of the bacteria's own genes. "We've identified the genes within bacteria that encode for lytic proteins—a very important component for cell survival and one that we can leverage against it," says Jackson. Bacteria use lytic proteins to make small nicks at strategic points within the cell wall so the cell can synthesize a new cell wall and divide.

With the lytic protein-producing genes identified, Jackson's team used the genes to drive synthesis of the encoded proteins in the laboratory and purified them. They then introduced the purified protein to the exterior of the bacterial cells. The results were quick and very clear—complete and total destruction of the pathogen's cell wall. Because these lytic proteins are unique to each bacterial species, the purified protein will only target that specific bacteria cell species, leaving other cells unharmed.

"The research also has shown that the purified lytic protein is very stable, with a long shelf life, and only extremely small amounts are required to quickly destroy bacterial cells," says Jackson. The team can sequence genomes and produce purified lytic proteins within a few weeks for unknown bacterial species or species that have not yet been sequenced.
Contact: Paul Jackson (925) 424-2725 (jackson80@llnl.gov).

Cerium's Unusual Behavior

Livermore researchers have found that a crystal of cerium—the chemical element that can be used for catalysts and fuel additives—behaves in unusual ways when subjected to high pressures. When a solid is pressurized, the internal energy at some point produces a change in the atomic arrangement, called a phase transformation, typically from one geometry to another. However, the scientists found that when cerium metal is exposed to 75,000 atmospheres of pressure, the atomic arrangement of the crystal simply shrinks and is transformed into two crystals.

Dan Farber, Kevin Moore, and Chantel Aracne-Ruddle showed that the two crystals are the same structure (one a large cube and the other a small cube) and have the same spatial orientation (the large and small cubes face in the same direction). That is, the two phases have the same crystal structure but different volumes. This finding is entirely unique in phase transformations of solid materials. The team, along with collaborators from several institutions in France, used a diamond anvil cell to create the intense pressures on the cerium crystal. They also

(*continued on p. 24*)

Commentary by Penrose (Parney) C. Albright

Dealing with the Nonlinear Battlefield

Photo courtesy of Tech. Sgt. Erik Gudmundson, U.S. Department of Defense

THE collection and analysis of overhead imagery has come a long way over the past 50 years or so. During the Cold War, analysts scrutinized overhead imagery at light tables, pouring over static scenes with which they were familiar and searching for significant changes. Analysts were typically assigned to count missile silos, look for large-scale troop movements, and spot long-range bomber deployments.

Since the Yugoslav wars in the early 1990s, the West has had few large-scale troop movements to monitor. We have attempted, sometimes successfully, to use imagery to find conventional military units—Serbian tanks and artillery, for example—but we now also recognize the importance of being able to track the movements of small groups of people and individual vehicles. In doing so, we could potentially locate safe houses and arms caches and provide general situational awareness in an environment where the enemy would disperse its forces to avoid U.S. airpower and where no clear boundary separated small enemy units from civilians and friendly forces. The battlefield has become "nonlinear."

The Yugoslav conflicts saw for the first time the U.S. beginning to use unmanned aerial vehicles (UAVs) as a significant tool. UAVs collected video, mostly of poor quality, over broad areas and kept objects in view until a weapon could be brought to bear. The deployment of UAVs implied the potential availability in future conflicts for huge amounts of dynamic imagery and the need for new analytic methods to process these data.

Our concern over the nonlinear battlefield and the need to deal with very small enemy units have been driven home in the current conflicts in Iraq and Afghanistan. The desire to detect the emplacement of an improvised explosive device or the transport of materials to and from a bomb factory has led to the concept of persistent surveillance of a village or city, including tracking the movements of vehicular and foot traffic and determining the location of enemy facilities. A further goal of persistent surveillance is to fuse collected data with other intelligence collection capabilities to determine the "human terrain" of social interactions and hierarchies.

Persistent surveillance implies continuous, full-motion, high-definition video over a broad area. However, transmitting such highly detailed visual data requires very large bandwidth, which cannot be streamed through the downlink from a UAV. Much of the current research in compression techniques is driven by the explosion of the Internet, but the information content that typical Internet users seek is not fully consonant with the needs of the military.

As described in the article beginning on p. 4, a Livermore system called Persistics permits real-time analysis of visual data by compressing unimportant (unchanging) features by a thousandfold and highlighting features of interest. Persistics capitalizes on the Laboratory's deep knowledge of sensor technology, our capabilities in high-performance computing, and our understanding of the Department of Defense's needs. Unlike other compression techniques that degrade quality, delete critical military data, or fail to achieve the needed compression, Persistics preserves relevant information in the scene, namely pedestrian and vehicular motion. Analysts assisted by real-time automated exploitation algorithms can obtain good situational awareness without having to examine every image manually. It is a highly creative solution to an important military problem and has been embraced by the Department of Defense.

A further requirement in dealing with the nonlinear battlefield is providing timely intelligence at the tactical level. After the Yugoslav conflicts, U.S. military strategists saw the advantage of transmitting just-acquired visual data directly to squad and platoon leaders instead of analyzed intelligence flowing down from the highest levels to brigade and company commanders. This once-controversial concept, now widely accepted, forces the issue of providing the sergeant or corporal with data that are easy to interpret. These soldiers consistently ask for full-motion video. Again, we see a mismatch between the need for data, the lack of associated bandwidth, and the number of analysts required to draw timely conclusions. Addressing this issue is a Department of Defense priority and the focus of one of the Laboratory's mission enhancement initiatives. As exemplified by the Persistics team, the creativity associated with Livermore's multidisciplinary culture, and its capabilities and infrastructure, will have an enormous effect on the American soldier.

■ Penrose (Parney) C. Albright is principal associate director for Global Security.

From Video to Knowledge

Livermore's Persistics

data-processing pipeline

combines graphics-based

computer hardware

and clever software to

extract meaning from

wide-area overhead

surveillance video.

Unmanned aerial vehicles, such as the Predator shown here, use multiple cameras for persistent surveillance. (Courtesy of Department of Defense.)

UNMANNED aerial vehicles, such as the drones Predator and Reaper, are rewriting the rules of battle in Iraq and Afghanistan and are being considered for monitoring U.S. borders. Operated by remote control, sometimes thousands of kilometers from the battlefield, the aircraft use multiple cameras to track and destroy the enemy.

These drones can fly several kilometers high, hover over targets for 24 hours and longer, and are often armed with bombs and air-to-ground missiles. By finding, tracking, and monitoring people, vehicles, and events of interest on a continuous basis with wide-area video cameras, the aircraft provide persistent intelligence, surveillance, and reconnaissance (ISR). In theory, persistent ISR coverage can prevent enemies from evading overhead surveillance systems, thereby enabling fast decision making for tactical missions, with reduced risk to U.S. forces and noncombatants.

A new Livermore computational system is designed to help the Department of Defense and other agencies monitor tens of square kilometers of terrain from the skies, with sufficiently high resolution for tracking people and vehicles for many hours at a time. The system, called Persistics, promises to overcome a severe and growing problem: the overwhelming volume of video data generated by modern overhead imagery. Military wide-area video surveillance cameras such as Constant Hawk and Angel Fire are collecting ever-increasing amounts of valuable video imagery over large geographic areas. However, the technology to promptly process, store, and extract meaning from data, and then transmit this information over long distances for further analysis, has lagged far behind.

Data Overwhelm Capabilities

"Sensing capabilities for wide-area video reconnaissance have evolved to far exceed our wildest expectations," says physicist Sheila Vaidya, principal investigator for Persistics and deputy program director of Defense in Livermore's Global Security Principal Directorate. "There exists an enormous—and growing—gap between the amount of information continuously collected by existing sensors and our ability to quickly take advantage of that information.

Advanced and accurate analysis techniques are urgently needed by the people who are tasked with categorizing, indexing, annotating, and drawing conclusions from the petabytes of data collected daily in theatre operations."

Computer scientist Mark Duchaineau, one of Persistics' key architects, says, "The data-processing infrastructure for national security is not designed for the amounts and types of data being generated by unmanned aerial drones relative to the scale of human resources available to analyze them through conventional 'VCR playback' style of viewing." In addition, the communication bandwidth supporting data transmission from air to ground and the archive storage capability are much too slow or too small to support fast-turnaround human analyses.

Duchaineau says, "Several years ago, Department of Defense managers presented us with this interesting processing challenge." The Livermore scientists knew they needed to work on the software side to get the most information out of the streaming video imagery. The greatest opportunity for helping tackle this challenge lay in the development of advanced algorithms (short computer programs) implemented on new computer architectures.

Persistics, the product of several years' effort, is an innovative data-processing "pipeline" that takes a radically different approach to addressing the video-data overload challenge. (See the box at right.) The technique retains the level of detail necessary for detecting anomalies while at the same time compressing the unchanging "background" and everything in motion by about 1,000 times without losing pertinent information. As such, the approach ameliorates the dearth of communication bandwidth for transporting video without losing image fidelity. Indeed, Persistics

technology can produce subpixel resolution for the background and any "movers" (people and vehicles), thereby allowing for additional analyses of suspicious activities. A single pixel can correspond to anywhere from several square meters to less than 1 square meter of real estate.

The Persistics architecture can support near real-time monitoring for tactical combat missions as well as forensic analysis of past events. Its analysis algorithms permit surveillance systems to "stare" at key people, vehicles, locations, and events for hours and even days at a time while automatically searching

with unsurpassed detail for anomalies or preselected targets. The Livermore breakthrough combines optimized hardware featuring the newest generation of graphics chips (typically used for computer gaming) with innovative algorithms. Some algorithms focus on compressing data while others analyze the streaming video content to automatically extract items of interest.

The system stabilizes incoming video imagery through extremely accurate calibration of onboard cameras and correction of pixel-to-pixel intensity variations. In this way, a mosaic made from hundreds of individual sensors

Inside Persistics

The Persistics data-processing "pipeline" uses a technique called pixel-level dense image correspondence to stabilize video, eliminate parallax (the slight differences in the apparent positions of objects viewed from different cameras), compress background, and provide unprecedented subpixel resolution of moving objects of interest. Dense image correspondence compares the scene from one pixel to another and corrects for individual differences.

"If we know precisely how any two video images relate to one another, we can remove parallax and determine what is background and what is moving, increase signal-to-noise ratio, and increase resolution to see details on vehicles," says computer scientist Mark Duchaineau. The biggest benefit, however, is the ability to compress data without throwing away important information.

The technique allows for image stability, which is essential for accurate

(left) In the manual stitch image, the road does not line up between the collected images.
(right) Dense image correspondence corrects for intensity variations between cameras to provide a seamless image.
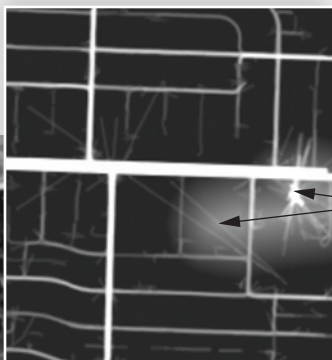
Spurious tracks

(left) Persistics allows analysts to automatically follow individual vehicles. In this scenario, a vehicle is tracked after a meeting at a presumed safe house (red box) as it travels (green line) to another building. (above) Persistics can extract a road network from flowing traffic and show vehicle motion in a "heat map" representation of traffic density to automatically discern if the traffic pattern changes. Spurious tracks can be caused by the glint of sunshine and other factors.

and high-resolution object identification and tracking. It also permits "seamless stitching," a process that optically combines images from multiple cameras to create a virtual large-format camera. To do this, individual cameras must be finely calibrated to account for relative stitch position and intensity differences, lens distortion, and pixel-to-pixel variations. The resultant mosaic behaves like a single sensor for Persistics to perform the necessary huge data reduction.

A requirement for Persistics' thousandfold data reduction is the continual revisit of a surveillance platform over a specified area. The increasing coherence of a scene built up over many passes produces high-fidelity backgrounds from which it is easy to spot movers. By having an aircraft circle the same area, Persistics can calculate the effect of parallax, which causes the perspective to constantly rotate. The corrected image provides a straight-down view of highly detailed terrain. "Removing parallax

makes it much easier to determine what is in reality moving in the background," says Persistics project leader Holger Jones. Current processing techniques use global registration, which generates many false-positive movers (people and vehicles).

Persistics is efficient in allotting processing resources to where they are most needed. For example, it can automatically direct additional computing power to track a particular convoy of vehicles in real time or keep watch over a group of Marines who are asleep in a poorly defended area.

Global registration

Dense correspondence

Persistics uses parallax-removing pixel-level dense correspondence to register two images and detect what has changed in the time period between capturing each image. The left image shows the original aerial video view. In the center, two images of the aerial view have been corrected with the traditional method of global registration. Because of parallax motion, some buildings as well as moving vehicles are detected. The right image corrected with dense correspondence shows only vehicles in motion (the bright areas); Persistics has removed the static background.

Persistics software is currently housed on a high-density 12-node minicluster, providing an aggregate 40 trillion floating-point operations per second of computing capability. Each node contains a combination of central processing units and seven graphics processing units. Pictured are (left) Sheila Vaidya and Holger Jones.

(a) The Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System (ARGUS-IS) has four stabilized lenses (telescopes), which together use 368 5-million-pixel cell phone cameras. (b) A mosaic of the 368 individual images is stitched together to form one wide-angle seamless image from which details can be extracted.

can be represented as an image from a single camera. This procedure allows the system to exploit the spatial and temporal redundancy in the data and tease out movers from the static background.

In Use at Ground Stations

In collaboration with the National Geospatial-Intelligence Agency, Defense Advanced Research Projects Agency (DARPA), Air Force, Army, and several Department of Defense laboratories, Livermore is incorporating the Persistics pipeline into data-processing ground stations fed with video data from Constant Hawk video cameras onboard both unmanned and manned aircraft. Recent tests of Constant Hawk imagery have validated Persistics' approach, demonstrating 1,000-times compression of raw video collections while maintaining high fidelity. In comparison, compression of still images can reduce data content tenfold, while standard video compression can achieve at best a 30-times data reduction.

Analysts working at ground stations will interact with the transmitted airborne video data. For example, Persistics has been integrated into the Air Force Research Laboratory–developed Pursuer viewer to allow analysts to pan, zoom, rewind, query, and overlay maps and other

metadata. With this viewer, they can use Persistics to make requests such as, "Give me the frames that recorded this vehicle from one to two o'clock this a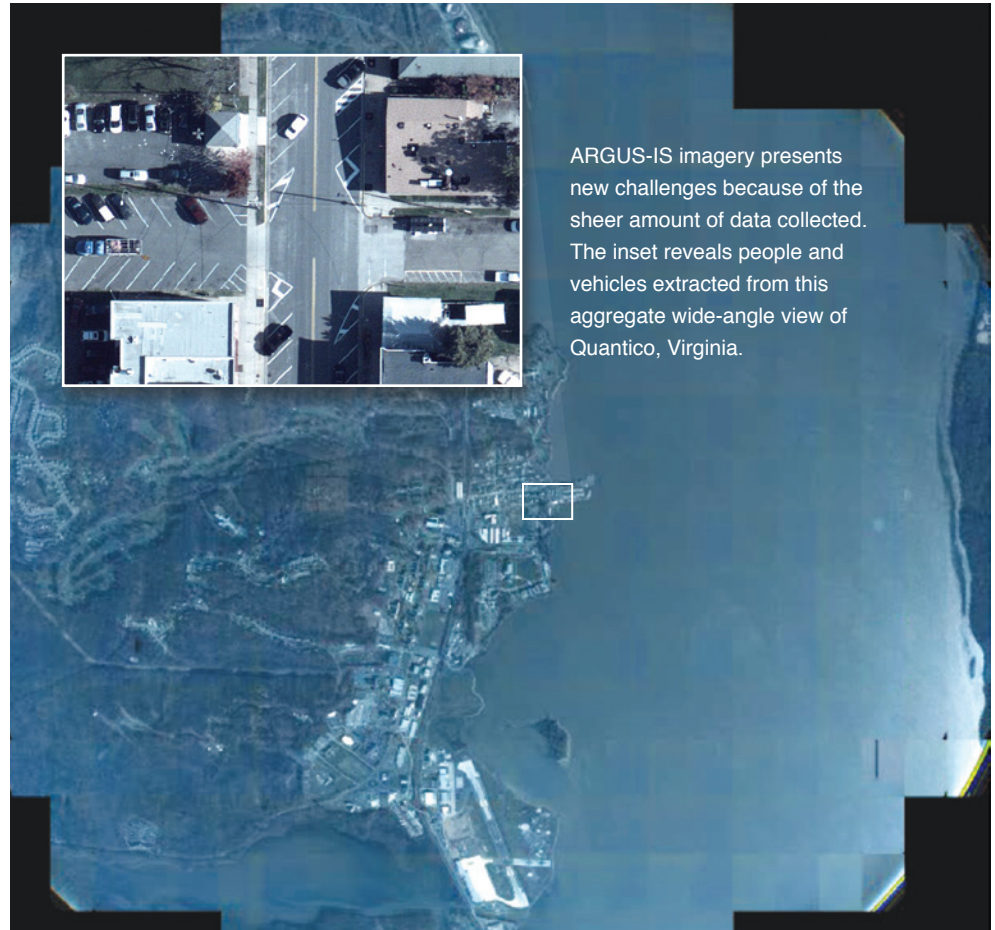fternoon," or "Show me all the vehicles that stop at this location today." Says Persistics project leader Holger Jones, "With Persistics, analysts can determine the relationships between vehicles, people, buildings, and events."

Persistics data-processing modules rely on commercial video-processing hardware designed for computer graphics, video editing, and games. "GPUs [graphics processing units] continue to grow in power, while shrinking in size and energy requirements," says Jones. In fact, their processing power is outpacing that of central processing units (CPUs), which run most computer operations. "We're riding the GPU technology wave," says Jones.

Vaidya led a former project that researched how GPUs might be programmed and used in knowledge-discovery applications relevant to national security. "We realized these processors—traditionally designed for fast rendering of visual simulations, virtual reality, and computer gaming—could provide efficient solutions to some of the most challenging computing needs facing the intelligence and military communities," says Vaidya. (See *S&TR,* November 2005, pp. 19–20.)

The Persistics software is currently housed on a 12-node minicluster, and each node contains a combination of CPUs and GPUs. To help meet ISR requirements in a cost-effective manner, the Livermore Persistics team has optimized a combination of microprocessors and high-end graphics cards found in both gaming boxes and many personal computers. When combined with a high-speed network and software tools written in open-source (not vendor-proprietary) code, the clusters outperform larger and more expensive proprietary engines in extracting

ARGUS-IS imagery presents new challenges because of the sheer amount of data collected. The inset reveals people and vehicles extracted from this aggregate wide-angle view of Quantico, Virginia.

information from visual data. (See *S&TR,* November 2004, pp. 12–19.)

Persistics Coming On Board

Although the current Persistics configuration is designed for ground-station processing, Livermore researchers are working to shrink the size, weight, and power requirements to permit mounting of the system onboard surveillance craft within two years. Developers are exploring the trade-off between data compression, image fidelity, and computing requirements to successfully evolve the next-generation architecture that will support onboard flight processing of massive data sets.

Persistics is being further enhanced to work with DARPA's newest generation of real-time persistent surveillance capability

called the Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System (ARGUS-IS). This system to detect and track events on battlefields and in urban areas can cover 100 square kilometers, a significantly greater aerial footprint than current systems. The ARGUS-IS video-collection rate of 12 hertz (frames per second) is considerably greater than previous systems, which operate at 2 hertz. ARGUS-IS comprises 368 cameras of about 5 million pixels each, identical to those used in cell phones. The cameras operate together behind four high-quality telescope lenses. In all, ARGUS-IS has 1.8 billion pixels compared with 4 million pixels in the first Sonoma sensor (the predecessor to ARGUS-IS) developed at Livermore in 2003, 176 million pixels

in the most advanced Sonoma sensor developed in 2007, and 800 million pixels in the sensor developed in 2009 by the Massachusetts Institute of Technology's Lincoln Laboratory.

Persistics can simultaneously and continuously detect and track the motion of thousands of targets over the ARGUS-IS coverage area of 100 square kilometers. ARGUS-IS can generate several terabytes of data per minute, hundreds of times greater than previous-generation sensors. "Until now, we had no practical way to store that much data," says Jones. "With Persistics, we have an innovative method to compress the equivalent of thousands of hard drives to just a few drives."

Decades of Visualization Research

About 30 people are involved in the Persistics effort, including computer scientists, electrical engineers, optics experts, statisticians, and machine-learning specialists who draw meaning out of visual data, a core Livermore strength. The

Laboratory has been conducting research in ISR for two decades. Previous efforts include designing advanced sensors and large, lightweight optics; analyzing space imagery; and inventing instruments to detect adversarial clandestine activities associated with weapons of mass destruction. In addition, Livermore computer scientists are developing methods to manage large volumes of visual data and automated techniques to extract meaning and make discoveries from that information for national security applications.

Among other accomplishments, researchers have pioneered methods to locate areas of interest in three-dimensional simulations of nuclear weapons physics generated by supercomputers performing trillions of operations per second. Laboratory scientists have also developed computer-automated techniques to search for microscopic flaws in glass optics used in the National Ignition Facility, the world's most energetic laser.

Many federal agencies are interested in Persistics applications, including the Department of Energy, Department of Defense, and Department of Homeland Security. Collaborations in ISR for nuclear safeguards and treaty monitoring support extend to international organizations such as the International Atomic Energy Agency and the Comprehensive Nuclear-Test-Ban Treaty Organization.

Over the past decade, Livermore researchers have studied the vexing issue of sensor output growth far outpacing human capabilities to ingest and react to the collected data in a timely manner. Early work, funded through the Laboratory Directed Research and Development Program, focused on developing software techniques that could first "quiet" the jittery video taken onboard a moving airborne vehicle buffeted by the atmosphere and then compress the data. The research effort grew into the Department of Energy project called Sonoma, which developed

Persistics researchers are developing the capability to produce three-dimensional images from overhead video data.

wide-area sensors for monitoring nuclear nonproliferation. The Sonoma Persistent Surveillance System featured wide-area views at high resolution, real-time onboard data processing, and high-performance visualization at the receiving end. In 2006, the Sonoma Project team received an R&D 100 Award for their innovation. (See *S&TR,* October 2006, pp. 4–5.)

"People in the Department of Defense got excited because they realized they could use the same techniques to look for terrorist activities," says Duchaineau. In 2005, the video-camera effort that began with Sonoma was passed to the Department of Defense, which developed Angel Fire for the Air Force and Marine Corps and Constant Hawk for the Army. ARGUS-IS, built by BAE Systems, Inc., is the newest imaging system.

During Sonoma's development, DARPA managers turned to Livermore to explore avenues for reducing the massive volume of data collected by these new sensors without sacrificing image

quality. Vaidya recalls, "Our inability to transport the data to ground in an efficient manner had become a bottleneck." Persistics provides not only an efficient means of stabilizing and compressing video to transport it across limited bandwidth channels but also back-end anomaly detection and behavior analysis to differentiate between normal and abnormal patterns of behavior.

Fast Forward or Rewind

Persistics video processing is event-driven, meaning its algorithms are designed to detect in real-time potentially important events in the streaming video data. The pipeline can detect moving people and vehicles and track them over many hours. Automatic recognition of certain scenarios can provide early warning of a threat and greatly strengthen tactical combat support. For example, allied forces could intercept terrorists in the process of planting an improvised explosive device or setting up for an allied base attack. Livermore scientists are also developing automated methods for identifying patterns of behavior that could indicate deviations from normal social and cultural patterns as well as networks of subversive activity.

At the other end of the spectrum, Persistics supports forensic analyses. Should an event such as a terrorist attack occur, the archival imagery of the public space could be reviewed to determine important details such as the moment a bomb was placed or when a suspect cased the targeted area. With sufficiently high-resolution imagery, a law-enforcement or military user could one day zoom in on an individual face in a heavily populated urban environment, thus identifying the attacker.

Looking Ahead

Livermore researchers continue to optimize the Persistics platform so it can

be carried aloft. That effort should be made easier this year because the size of GPUs is expected to shrink yet again, with power consumption reduced in half by late 2011. "As we ride the GPU technology wave, we should have the system up in the air by 2013," says Vaidya. "We plan to stream to ground only the information that is pertinent to the end user, which may require a synergy of multiple sensors in the air to provide robust estimates of what's important."

Persistics technology will soon be made available as open source to the government and subcontractors. The technology is modular to allow future plug and play, as Livermore scientists develop additional automated techniques. For example, they are researching ways to make possible the three-dimensional viewing of targets, which could further enhance data compressibility. They are also exploring methods to overlay multiple sensor inputs—including infrared, radar, and visual data—and then merge data to obtain a multilayered assessment.

Vaidya notes that unmanned aircraft have demonstrated their ISR value for years in Afghanistan and Iraq. As U.S. soldiers return home, the role of overhead video imagery aided by Persistics technology is expected to increase. Persistics could also support missions at home, such as monitoring security at U.S. borders or guarding ports and energy production facilities. Clearly, with Persistics, video means knowledge—and strengthened national security.

—*Arnie Heller*

Kinetic Models Predict Biofuel Efficiency

WITH demand for liquid transportation fuels growing steadily and projections of dwindling petroleum-based fuel supplies becoming a reality, interest in the use of biodiesel fuels to replace or blend with conventional fuels for aircraft and automotive applications is on the rise. Because plants consume carbon dioxide via photosynthesis, these renewable fuels offer the potential to be carbon neutral. Biomass products, such as ethanol and n-butanol produced from fermentation of plant materials, may replace or supplement gasoline in spark-ignition engines and in conventional jet and diesel fuels.

Biodiesel fuel is produced from oils in soy, canola, coconuts, linseed, jojoba, olives, peanuts, and other plants as well as from beef tallow and other animal fats. Another source with great promise is bioengineered algae that can be grown in large vats, a practice that does not compete for fertile soil. Biodiesel fuels are produced by esterification, the process of combining oil with methanol to produce methyl esters. These fuels can be used in diesel engines without significant engine modification. In fact, the original engine that Rudolph Diesel demonstrated at the 1898 Exhibition Fair in Paris, France, ran on biodiesel produced from peanut oil.

Bio-derived fuels have important chemical differences from petroleum-based fuels, which affect their performance, efficiency, and pollutant emissions. The Livermore combustion chemistry group, led by Bill Pitz and Charlie Westbrook, has spent years developing computer modeling capabilities that provide information about biofuels' combustive behavior. The team has used kinetic modeling to study methyl esters ranging from 1 to 20 carbon atoms in length as well as carbon chains with varying numbers of carbon double bonds. "The resulting chemical kinetic reaction mechanisms present a predictive computational tool that can be used to explain, for the first time, the basic chemistry controlling biofuels' chemical processes," says Westbrook. Analyses using reliable detailed kinetic models can reveal data needed to simulate ignition, combustion, and emissions properties of these fuels.

Kinetic models based on elementary reactions offer the best accuracy and reliability, and the knowledge of a specific elementary reaction can be reapplied for completely different operating conditions and in different species mixtures. Detailed kinetic models represent the molecular interactions that occur when chemical bonds are broken and reformed into new chemical compounds. Much of the value of kinetic modeling lies in how dynamic simulations can reveal information about inherently complex chemical systems. In contrast, more approximate modeling methods have parameters determined strictly by fitting to experimental measurements, which limits their applicability. Much more information is contained in chemically reacting systems than can be extracted from simple inspection.

Chemical kinetic modeling codes are rule-based computations that predict how the composition of fuel affects energy conversion

> *The resulting chemical kinetic reaction mechanisms present a predictive computational tool that can be used to explain, for the first time, the basic chemistry controlling biofuels' chemical processes.*

performance and pollutant emissions. Kinetics refers to the study of physicochemical (including biological) systems that change with time. The Livermore model, which emulates how real-life systems operate, uses a large set of differential equations to represent physical and chemical processes known or hypothesized to occur in biological systems.

Burning Questions

Westbrook and Pitz spent five years developing models for methyl esters that include all pertinent species, reactions, rate coefficients, and related thermochemical and transport parameters as functions of temperature and pressure. Westbrook says, "The process was lengthy because the varied chemical compositions, such as carbon–carbon bonds, create differences in how each one burns." Kinetic mechanisms for this family of fuels had not been previously available.

Unlike the hundreds of chemical compounds in gasoline or diesel, biodiesel fuels contain a limited number of compounds. In the U.S. and Europe, the most common biodiesel fuels are made from soy and canola oils with differing amounts of the same five specific methyl esters: methyl palmitate, methyl stearate, methyl oleate, methyl linoleate, and methyl linolenate. Each biodiesel fuel consists of large fuel molecules, with chain lengths of 16 to 18 carbon atoms plus a methyl ester group at one end. (See the figure at right.) The numerical models for biodiesel fuels are therefore complex, with systems of coupled nonlinear differential equations that may have as many as 5,000 chemical species and 20,000 elementary chemical reactions. Because of the Laboratory's supercomputing facilities, the Livermore team is one of the few groups that can apply these complex models in simulations of realistic, practical combustion problems.
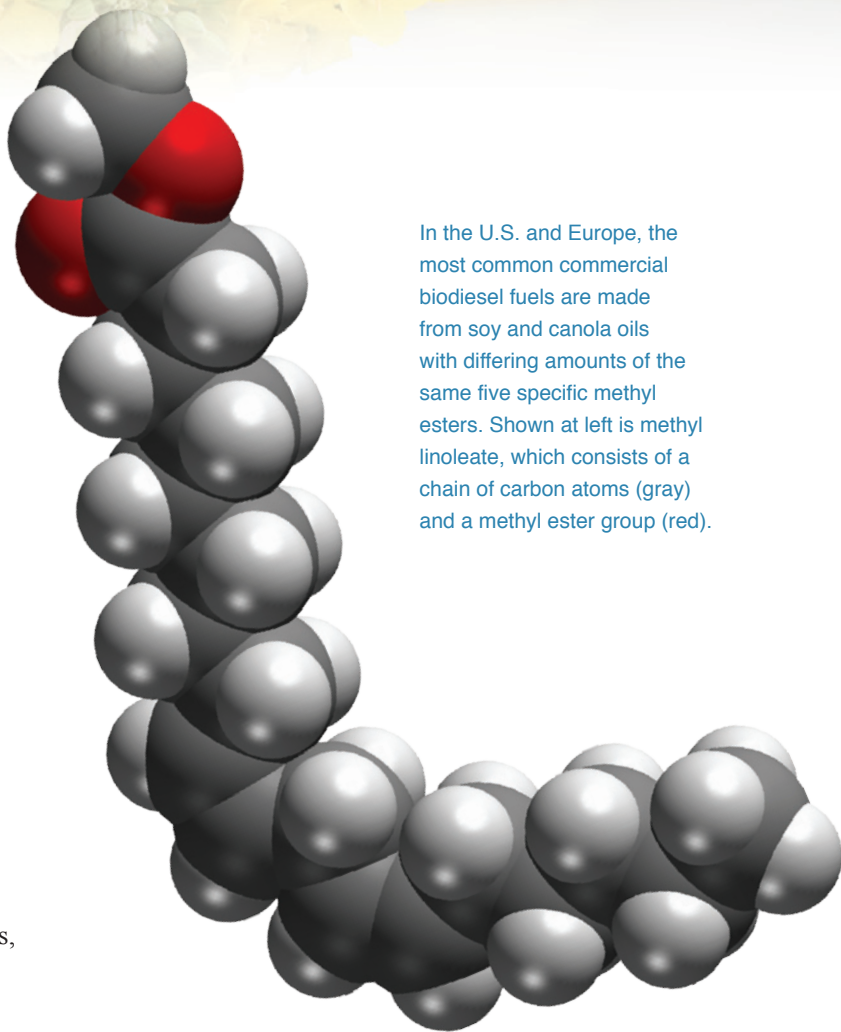
In the U.S. and Europe, the most common commercial biodiesel fuels are made from soy and canola oils with differing amounts of the same five specific methyl esters. Shown at left is methyl linoleate, which consists of a chain of carbon atoms (gray) and a methyl ester group (red).

Biodiesel stations such as this one in Berkeley, California, may one day be as common as those selling petroleum gas. The Biofuel Oasis is a worker-owned cooperative. (Courtesy of Biofuel Oasis.)

The combustion chemistry team found that the methyl ester group in biodiesel fuel weakens some of the bonds between carbon and hydrogen atoms. This effect makes the hydrogen atoms easier to remove, which sets the combustion process in motion. The critical metric of diesel fuel performance is its ease of ignition, as measured by its cetane number. The methyl ester group increases the cetane number of the fuel.

Phenomenal Insight

According to Westbrook and Pitz, oxygen atoms present in biodiesel fuel molecules have a beneficial property. A pollution problem with diesel engines has historically been their tendency to produce soot and smoke, but oxygen in the methyl ester group leads to lower soot emissions from diesel engines when using biodiesel fuel. When oxygen-containing compounds are blended with conventional diesel fuel, soot production can be sharply reduced. Although this effect of oxygen had been observed experimentally in the early 1990s, the Livermore chemical kinetics models provide the first fundamental understanding of chemical processes responsible for the phenomena.

Combustion modeling results are validated with experiments and the relatively small body of existing experimental literature before being used in simulation codes that optimize engine design for maximum efficiency and minimal pollutant emissions. Understanding the kinetics of the reactions occurring in biodiesel fuels at both high and low temperatures is necessary to reliably simulate ignition, combustion, and emissions in diesel and homogenous charge-compression ignition engines. The Laboratory provides data to many university researchers worldwide who are performing experiments.

"As a rite of passage, many postdocs from these universities spend a year at Livermore working with our group," Westbrook says. "Over the years, an international family has developed, all of us engaged in the pursuit of petrochemical alternatives." Westbrook and Pitz are studying other plant and animal fat mixtures in an effort to develop and evaluate future transportation fuels.

—*Kris Fury*

Going Deep with MEGa-Rays

WITH a name like MEGa-ray, for mono-energetic gamma-ray, it is tempting to imagine this light source being used as a weapon by Luke Skywalker, especially when one considers that its beams will be the most powerful and brightest ever. In fact, the MEGa-ray light source is much like a laser, but it generates gamma rays rather than a visible-light beam, and the device is certainly not a weapon.

Project leader Chris Barty, chief technology officer for the National Ignition Facility and Photon Science Principal Directorate, says, "This new technology will produce photons at extremely high energies with the brightness and the spectral, spatial, and temporal density needed to study the nuclei of individual isotopes." Backscattering is key to MEGa-ray brightness

and density. In laser-Compton backscattering, short laser pulses collide head-on with short bunches of electrons moving at relativistic speeds, or almost the speed of light. (See the figure below.) The collision creates photons that backscatter, or move in the original direction of the electron beam. This scattered gamma radiation is Doppler upshifted in energy by more than a million times and directed forward in a narrow, polarized, laserlike beam that can be "tuned," or adjusted, to different wavelengths. "We have spent almost a decade optimizing Compton backscattering to achieve such high-brightness, narrow-bandwidth gamma rays," says Barty.

By tuning the MEGa-ray light source to very precise energy levels, researchers can detect, image, and even assay specific
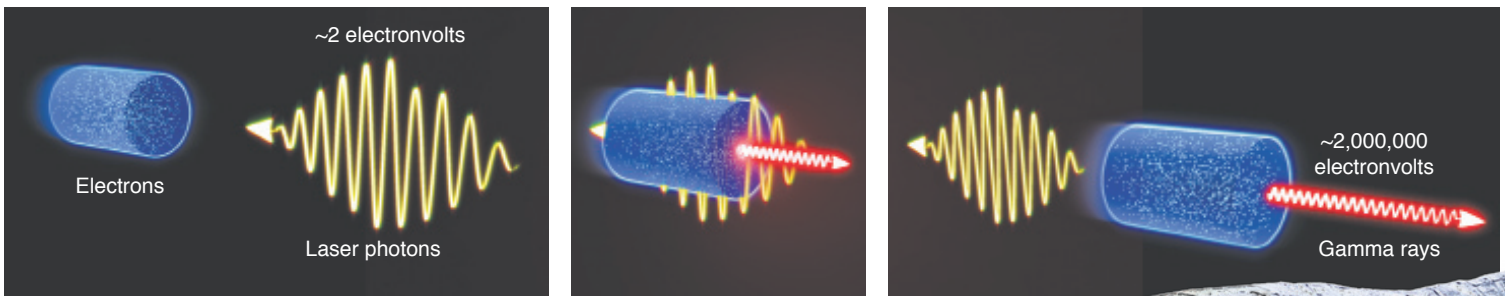
(above) In the mono-energetic gamma-ray (MEGa-ray) device, electrons and laser photons crash head-on, creating a backscatter of gamma rays that is 1 million times more powerful than the incoming photons. (Rendering by Kwei-Yu Chu.) (below) A new-generation MEGa-ray device is named for the velociraptor dinosaur.

nuclei in objects containing a variety of isotopes. In 2008, proof-of-principle experiments demonstrated a first-generation MEGa-ray machine's ability to detect isotopes of low-density lithium shielded behind high-density lead and aluminum. Lead can effectively shield many materials from the prying eyes of conventional radiation detectors, so the MEGa-ray capability is truly remarkable.

MEGa-ray experimental systems can occupy an entire large room, but making one small enough to fit into a portable truck trailer is high on Barty's agenda. With a MEGa-ray device and its accompanying detector in a truck trailer, it can be moved, say, to a port for examining the contents of cargo containers or to a nuclear power plant for measuring precisely how much usable fuel remains in fuel rods.

Far Beyond X Rays

X rays have been used since their accidental discovery in 1895 to view the invisible: bones beneath skin, silver fillings in teeth, and metal enclosed in plastic. The shadow pattern of an x ray results from the absorption of photons by the higher density material.

However, x rays have their limits. Distinguishing weapons-grade uranium from depleted uranium requires higher energy and more sophisticated photon beams than conventional x-ray machines can provide. Synchrotron beams are likewise lower in energy and incapable of characterizing heavy elements such as uranium. In contrast, the vastly increased brightness and monochromatic nature of a MEGa-ray beam can efficiently excite, or fluoresce, specific isotopes of both light and heavy elements to identify an object's isotopic contents. In addition, the higher energy

of these gamma rays allows scientists to see objects more deeply buried. At 2 million electronvolts, a MEGa-ray beam has roughly 50 times the penetration capability of a conventional chest x ray.

Fluorescence is the emission of radiation by a substance during exposure to external radiation. The most common form of fluorescence is visible light that comes from exciting electrons in an atom. Nuclear resonance fluorescence (NRF) goes deeper. As its name implies, NRF's gamma rays excite the nucleus, which fluoresces as it relaxes.

Says physicist James Hall, who leads the team developing the MEGa-ray detector, "Each isotope has a fundamentally different resonance. For a nuclear power plant fuel rod, we would tune the MEGa-ray beam to uranium-235 to measure how much of the isotope remains in the rod." It would be tuned differently to identify shielded plutonium. To aid the Department of Homeland Security's FINDER Project for detecting nuclear materials at ports, the light source could be tuned to search for the particular material of concern. All identifications could be made unobtrusively, nondestructively, and at very low dose levels, well below allowable limits for humans.

Smaller, More Powerful

Construction has begun at Livermore on a smaller, next-generation MEGA-ray light source called VELOCIRAPTOR (Very Energetic Light for the Observation and Characterization of Isotopic Resonances and the Assay and Precision Tomography of Objects with Radiation). The new light source builds on the Thomson-Radiated Extreme X-Ray (T-REX) system, Livermore's first MEGa-ray project funded by the Laboratory Directed Research and Development Program. (See *S&TR*, December

MEGa-ray beam absorption technologies currently under development could detect a piece of uranium-235 smaller than 5 millimeters in less than a second. This speed and accuracy would make the MEGa-ray system an excellent tool for examining cargo containers, trucks, and other loads on the move.
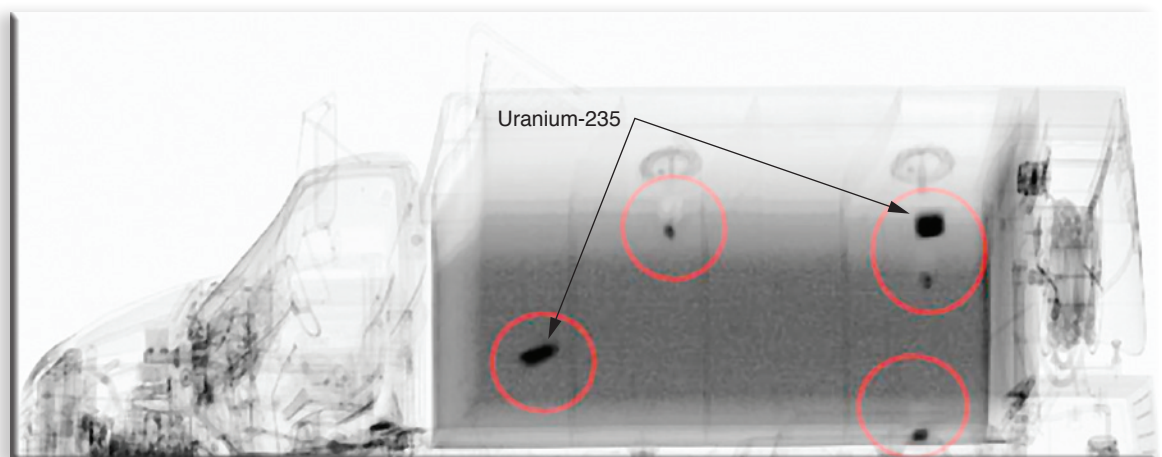
2006, pp. 16–17.) (Thomson and Compton backscattering are closely related.)

The very name of the next-generation light source indicates its smaller size. Anyone who saw the movie *Jurassic Park* will remember the tough, nasty little velociraptors. Livermore's VELOCIRAPTOR won't be tearing scientists limb from limb but will, over just a few meters, produce about a million times higher peak brightness than its predecessor. Collaborators include the Department of Homeland Security's Domestic Nuclear Detection Office and SLAC National Accelerator Laboratory. The latter contributes its advanced accelerator technology to the project.

"Demonstrations of the technologies required for the MEGa-ray truck-trailer assembly are anticipated in 2013, with an integrated portable source demonstration possible by 2018," says Barty. A portable MEGa-ray source and detector will enable hands-free precision assays and images of nuclear waste canisters, cargo containers, nuclear fuel rods, and other objects that might house uranium or plutonium.
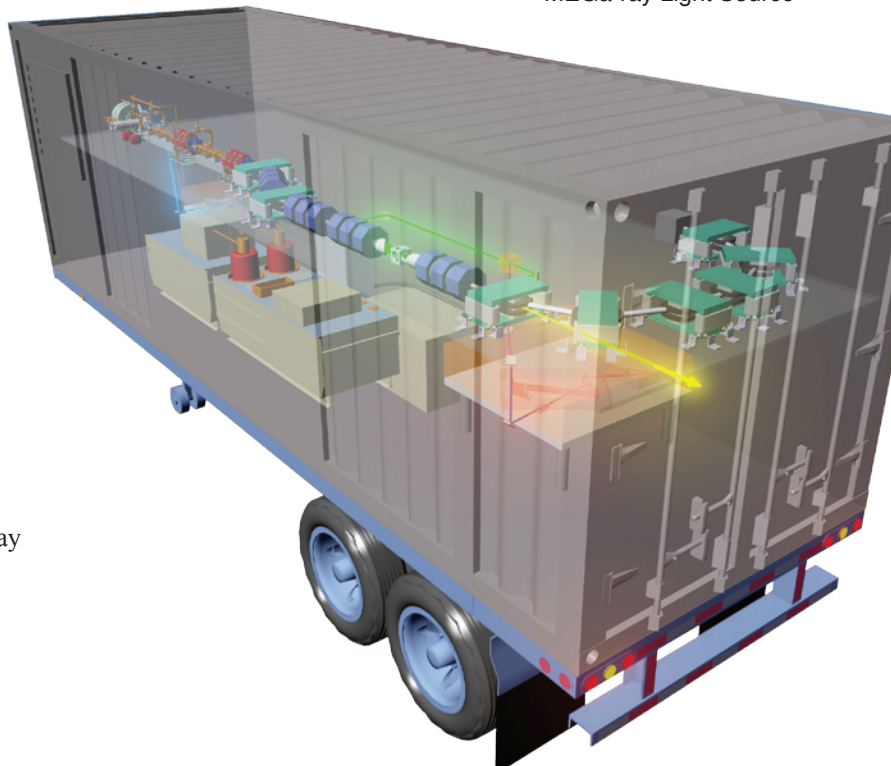
A MEGa-ray device and its accompanying detector in a truck trailer could allow rapid detection of nuclear materials in the field. (Rendering by Clayton Dahlen.)

The DINO Detector

While work on the MEGa-ray light source progresses, Hall's team is developing the Dual Isotope Notch Observer (DINO), a detector system that should be capable of measuring NRF reactions in materials induced by intense MEGa-ray beams. The DINO NRF detectors will use pairs of "witness foils," the first made of the resonant isotope of interest such as uranium-235, and the second made of a nonresonant counterpart, such as uranium-238.

Says Hall, "If the resonant isotope being scanned is not present in the object under inspection, then a significant amount of NRF will be generated in the resonant witness foil of the DINO detector system. On the other hand, if the resonant isotope is present in the object, then the resonant photons at the peak of the MEGa-ray beam will be heavily absorbed in the object, creating a 'notch' in the transmitted beam. Less NRF will thus be generated in the resonant witness foil."

In practice, one would evaluate the ratio of NRF signals obtained from the resonant and nonresonant DINO witness foils, because this ratio is, in principal, sensitive only to the resonant isotope of interest in the object being inspected. The method should thus allow for very clean and accurate isotopic measurements.

An object would be exposed to a continuous flux of MEGa-ray photons whose energy had been tuned to the NRF absorption resonance in the isotope of interest. The interrogating photons, whose energies might range from 1 to 8 megaelectronvolts, would be highly penetrating and able to "see" through many centimeters of steel. DINO detector systems are being designed to require minimal operator intervention and deliver minimal dose to the object, while also providing high throughput at commercial seaports, airports, and other points of entry.

A New Science

VELOCIRAPTOR will be located in a building at Livermore that formerly housed the Nova laser system. It is an ideal location for this powerful new gamma-ray light source in part because of the facility's existing 2-meter-thick walls.

"We have created a new science, one we call 'nuclear photonics,'" says Barty. "We believe that MEGa-rays have the potential to do for isotopes what the laser did for the atom." VELOCIRAPTOR will serve as the cornerstone for the Laboratory's unique Nuclear Photonics Facility.

—*Katie Walter*

Key Words: Compton backscattering, Dual Isotope Notch Observer (DINO), mono-energetic gamma-ray (MEGa-ray) light source, nuclear resonance fluorescence (NRF), VELOCIRAPTOR.

For further information contact Chris Barty (925) 423-8486 (barty1@llnl.gov).

Energy on Demand

FINDING effective means for harnessing power from energy sources has become a hot research area in recent years, spurred by the nation's ever-increasing demand for more power and the need to reduce consumption and reliance on fossil fuels. Renewable energy sources, such as solar and wind, could help reduce the carbon footprint. For centuries, hydropower has been the most productive form of renewable energy, and geothermal power has also been tapped to generate electricity to help meet consumer demand.

Unfortunately, hydro and geothermal sources are not always located in areas that make it easy to integrate them into the electric grid. Solar and wind power, on the other hand, may increase the possible locations where energy might be produced, but their energy production is intermittent—not always available or predictable. This quality makes it difficult for utility companies to effectively rely on these sources. In fact, utility companies need to provide an equal amount of backup power, often not from renewable sources, to ensure energy availability.
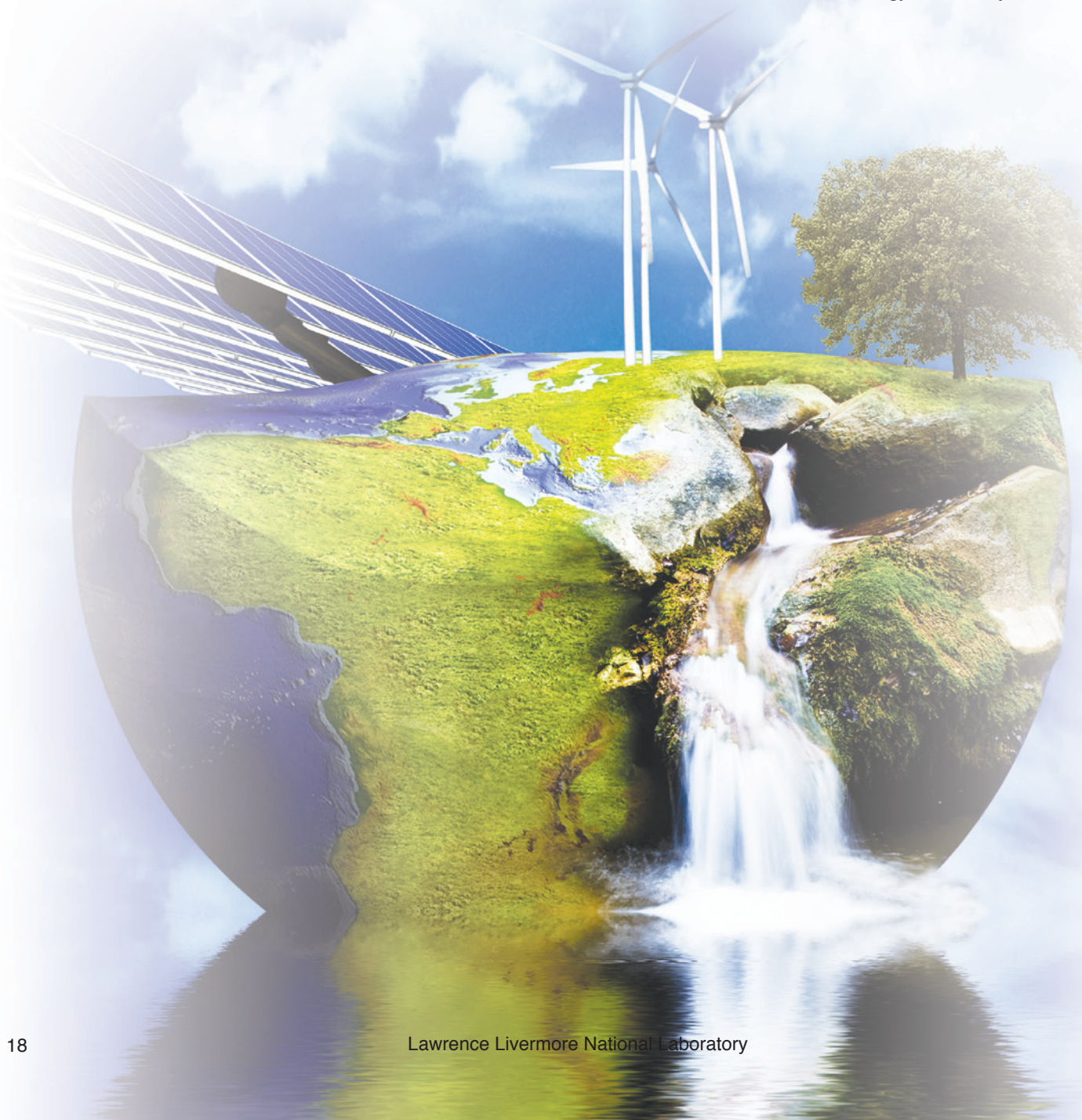
Storing energy from wind, solar, and conventional sources when conditions are favorable, so that it can then be used at a later time, such as when demand is high, may be the answer to this grid-integration problem. A novel electromechanical battery (EMB) designed by Livermore has the potential to provide maximum bulk storage of energy produced from a variety of sources with minimal energy loss. As part of a Cooperative Research and Development Agreement, Laboratory scientists are working with EMB Energy, Inc., which has engaged several other commercial partners including Arnold Magnetics Technologies Corporation, ATK, and Williams International, to build large, modular EMB storage systems capable of addressing the huge power-leveling requirements of the grid.

Livermore has had several decades of experience developing EMBs. Initial systems were designed for specialized, high-power applications where pulses of electricity were needed to ride through short interruptions in electrical power. "This technology was beneficial for facilities such as hospitals that cannot afford downtime in their power supply," says Laboratory physicist Richard Post, who has led EMB research efforts. "However, previous versions of the technology had energy losses that were too great for the device to be sufficient for energy storage applications, where the required storage time is many hours."

With several innovative technologies integrated into one, the newest EMB iteration is predicted to store energy for 6 to 8 hours, while releasing it over periods of 1 to 4 hours. In addition, unlike previous EMBs, which can waste 20 to 30 percent of their energy through internal losses, the newest EMBs have only a projected 5-percent energy loss.

With a highly aggressive schedule, this government–private industry partnership plans to build bulk storage EMBs for commercial deployment in 2012. The team will manufacture several EMB prototype devices, the final model being a 250-kilowatt-hour EMB. Ultimately, several hundred batteries will be configured in an underground array to capture, store, and dispatch energy gathered from various energy sources, including solar and wind. Once in the field, these novel systems will offer an energy boost to the grid, translating into savings for both utility companies and consumers.

Energy on the Fly

During Post's nearly 60-year career at Livermore, he has been the mastermind behind many inventions, including three distinct devices that have come together to create the bulk storage EMBs. A flywheel made from low-density, high-strength composite materials stores rotational energy for the system. A novel electrostatic generator–motor both powers up and discharges energy from the EMB system with the proverbial flip of a switch.

And, tapping into his expertise in magnetic fusion, Post developed "passive" magnetic bearings that stabilize the EMB system with no mechanical friction energy losses. All the components are encased in a sealed, cylindrical vacuum vessel, where they work in concert to store and extract electricity with high efficiency.

In the 1970s, Post was one of the first to point out that a material's strength per unit weight is what dictates its kinetic energy storage capacity. "The idea for using high-strength, low-density composite materials instead of high-density metals to create flywheels grew out of working with my son Steve on an EMB for electric vehicles," says Post. Together, they wrote an article entitled "Flywheels" for *Scientific American* that discussed approaches to designing flywheels using high-strength composites. At that time, flywheels were typically fabricated from metals such as steel because at a given rotational speed the more mass a material has, the more kinetic energy it can store. However, in the *Scientific American* article, they showed that a high-strength, lower

Cement casing

Vacuum vessel

Assembly

Components
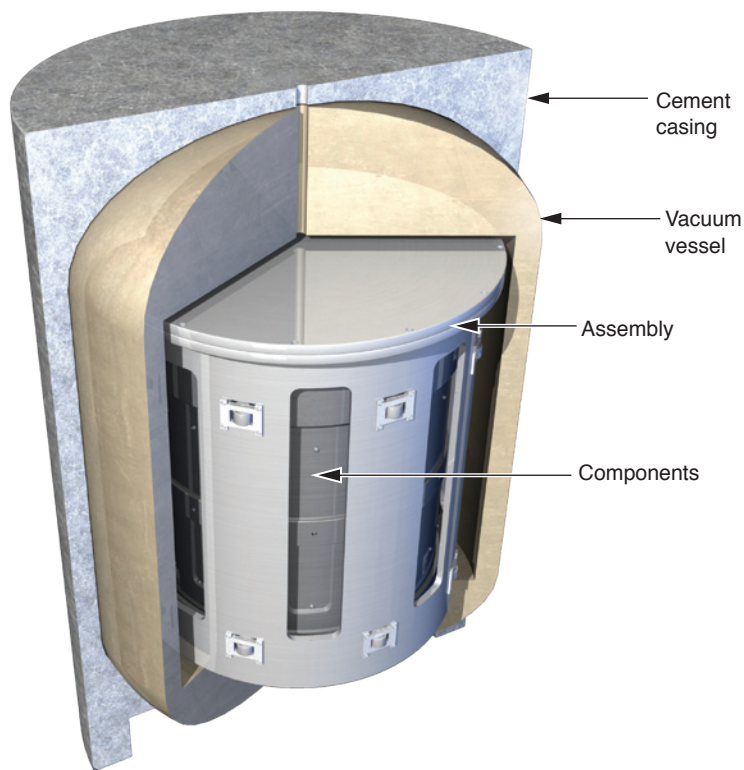
Livermore's electromechanical battery (EMB) unit consists of a vacuum vessel that houses an assembly containing a flywheel made from composite fiber material, an electrostatic generator–motor, and passive magnetic bearings, among other essential components. (Rendering by Kwei-Yu Chu.)

density material could be rotated at a much faster rate than steel, enabling the lighter weight flywheel to store more kinetic energy.

Over the last decade, composite materials have greatly advanced. They are not only stronger but also easier to manufacture, which substantially reduces their cost. A team led by Livermore engineer and composite materials expert Scott Groves has developed a high-strength, low-density carbon-fiber composite perfectly suited for EMBs. The next step is to determine the right material combinations for fabricating the flywheel and integrating it into the device.

Inside the vacuum vessel, the flywheel is an essential part of the rotor for the electrostatic generator–motor, and the two components are integrated into the same piece of hardware. To charge the EMB, the generator–motor feeds energy to the rotor–flywheel assembly, causing it to spin until it eventually reaches a maximum speed of tens of thousands of revolutions per minute. The device is then discharged by using the generator–motor to slow the rotor– flywheel assembly, thus drawing out the kinetically stored energy.

EMB
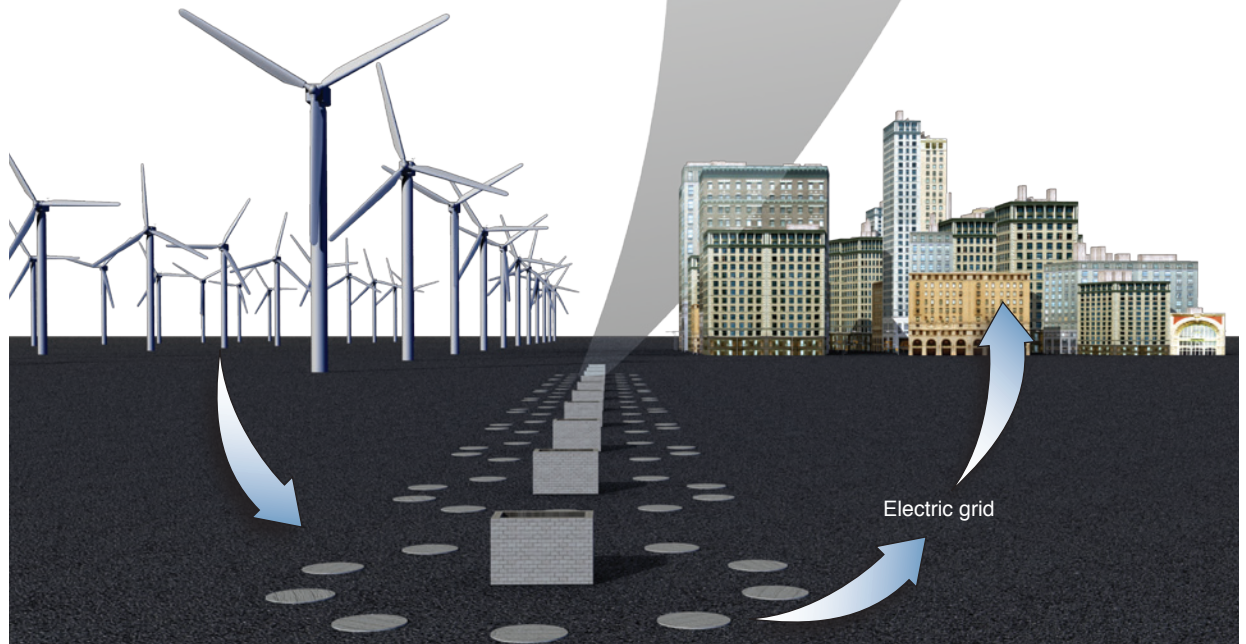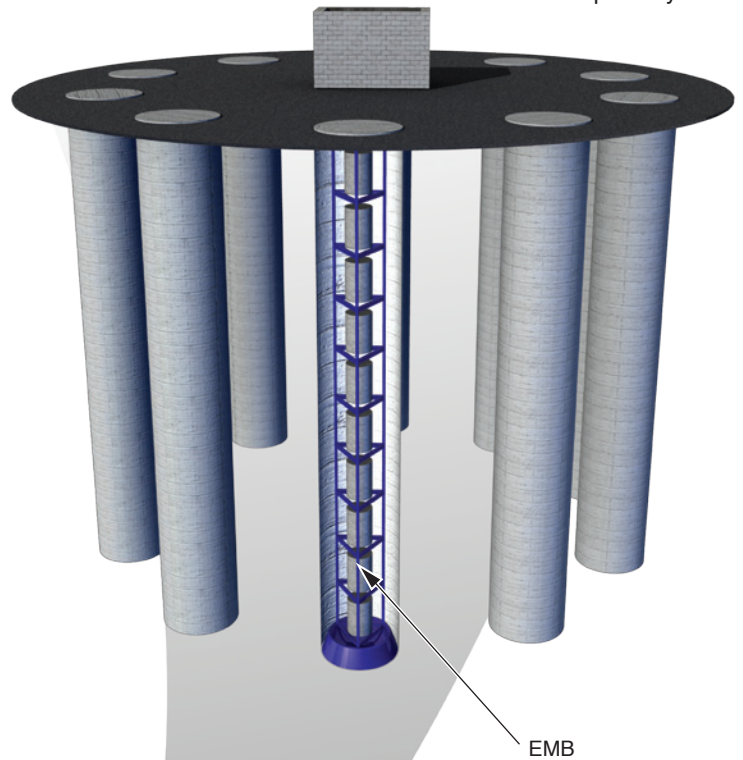
Electric grid

Several hundred EMBs will be configured in an underground array to capture, store, and dispatch energy from various energy sources into the electric grid. The power supplied by these devices could help utilities more easily meet consumer demand during peak usage. (Rendering by Kwei-Yu Chu.)

Unlike the more common flywheel-battery storage systems that use electromagnetic generator–motors, the electrostatic version has virtually no internal losses. Also, instead of using so-called "active" magnetic bearings that require electrical power, permanent "passive" magnetic bearings are used to dynamically stabilize the system without the need for complicated sensors, control circuits, and electromagnets.

Placed in a configuration known as a Halbach array, invented by the late Klaus Halbach of Lawrence Berkeley National Laboratory, the magnets are arranged to create a periodic magnetic field that is alternately vertical and horizontal. This arrangement concentrates the field on one side, while canceling it on the other. The passive magnetic bearings have very low losses, allowing the rotor–flywheel to continuously spin with minimal energy loss. All together, the passive magnetic bearings, electrostatic generator–motor, and composite flywheel make up a system that suffers far less energy loss and provides greater storage-time capability compared to standard EMB systems that contain electromagnetic or mechanical bearings and magnetostatic generator–motors.

Stepping Stones

Livermore researchers have successfully demonstrated prototypes of the electrostatic generator–motor with a small startup company and the passive magnetic bearings with Arnold Magnetics. Ultimately, the team will design several EMB prototypes, each serving as a springboard to the next, with the first one scheduled for completion this summer. Bob Yamamoto, the project's principal investigator, says, "The initial proof-of-concept will be a 5-kilowatt-hour battery about the size of a coffee urn that will demonstrate all the disparate parts fully integrated into a single homogeneous operational unit."

A 25-kilowatt-hour battery built in collaboration with Livermore's industrial partners will mimic the final product design but at a reduced scale. "This smaller version of the 250-kilowatt-hour battery will measure 2 meters in diameter and be about 30 centimeters tall," says Yamamoto. "The production-ready battery will be about 1.8 to 2.4 meters tall."

The commercial EMBs are expected to have decades of lifetime, as opposed to more common electrochemical batteries that in many cases must be replaced about every two years. Post points out that the new product should also be much less expensive to produce, and its potential safety hazards are well accounted for and easily controlled, unlike the more volatile, explosive nature of some electrochemical batteries.

As a result of EMB's cost-effectiveness, long life, and less hazardous nature, the device promises to be an enabling technology for the nation's smart grid, which is expected to be fully deployed within the next five years. The smart grid will use a wide array of technologies to dynamically respond to changes in grid conditions. "The timing is perfect for this technology," says Yamamoto. "Right now, the nation is focused on delivering cost-effective solutions for producing and storing energy. The new EMB technology melds a variety of technologies Dick has developed over the last several decades to create a unique, low-cost bulk energy storage technology that meets the nation's needs."

The Tip of the Iceberg

At the heart of EMB's success is the special relationship between the scientists, the Laboratory's Industrial Partnerships Office, and the commercial partners. "Through these collaborations, we have built a series of low-cost prototypes, at relatively low risk to our partnering companies, so we could prove each innovation separately," says Annemarie Meike, a Livermore business development executive who promotes and manages EMB technology transfer to private industry. "The communication exchange between innovators and manufacturers during this time has been invaluable, leading to robust relationships that will carry forward for this and other applications."

The current Cooperative Research and Development Agreement covers large-scale EMBs for bulk energy storage applications, but the EMB technology can be licensed for other purposes. "The device could be adapted for use as a power source for individual homes, which would be particularly useful in rural environments," says Post. Some day, EMB technology may even be used to power entire communities, independent of the grid. For now, EMBs are well on their way to providing a much needed resource for storing energy from intermittent renewable energy sources, propelling the nation toward more environmentally benign energy sources and a "greener" way of life.

—Caryn Meissner

Key Words: bulk energy storage, Cooperative Research and Development Agreement, electromechanical battery (EMB), electrostatic generator–motor, flywheel, Industrial Partnerships Office, magnetic bearings, renewable energy.

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.

S&TR April/May 2011

Patents

Polymerase Chain Reaction System Using Magnetic Beads for Analyzing a Sample That Includes Nucleic Acid
Shanavaz Nasarabadi
U.S. Patent 7,867,713 B2
January 11, 2011
A polymerase chain reaction (PCR) system for analyzing a sample with nucleic acid includes magnetic beads and a flow channel that has a PCR chamber. Adjacent to the chamber are a pre-PCR magnet and a post-PCR magnet. The nucleic acid binds to the magnetic beads, which then flow to the pre-PCR magnet in the flow channel. The magnetic beads and the nucleic acid are washed with ethanol, and the nucleic acid in the PCR chamber is amplified. The magnetic beads and the nucleic acid are then separated, with the beads flowing into a waste stream. The nucleic acid is added to a post-PCR mixture that moves through the flow channel to an analysis unit for characterization.

Sequential Addition of Short DNA Oligos in DNA-Polymerase-Based Synthesis Reactions
Shea N. Gardner, Raymond P. Mariella, Jr., Allen T. Christian, Jennifer A. Young, David S. Clague
U.S. Patent 7,871,799 B2
January 18, 2011
This method involves fabricating a DNA molecule of user-defined sequence. Multiple DNA sequence segments are preselected that will make up the DNA molecule of user-defined sequence. The DNA sequence segments are separated temporally. Then they are combined with at least one polymerase enzyme, and the DNA sequence segments are joined to produce the DNA molecule of user-defined sequence. Sequence segments may be of length n, where n is an even or odd integer. In one embodiment, the user specifies the length of the desired hybridizing overlap, and the sequences and the protocol for combining them are guided by computational (bioinformatics) predictions. In another embodiment, sequence segments are combined from multiple reading frames to span the same region of a sequence, so that multiple desired hybridizations may occur with different overlap lengths. In yet another embodiment, starting sequence fragments are of different lengths (for example, n, $n + 1$, and $n + 2$).

Passive Magnetic Bearing Configurations
Richard F. Post
U.S. 7,786,010 B2
January 25, 2011
A journal bearing provides vertical and radial stability to a motor of a passive magnetic bearing system, when the rotor is not rotating and when it is rotating. In the passive magnetic bearing system, the rotor has a vertical axis of rotation. Without the journal bearing, the rotor is vertically and radially unstable when stationary, and it is vertically stable and radially unstable when rotating.

Process for Fabrication of Cermets
Richard I. Landingham
U.S. Patent 7,879,285 B2
February 1, 2011
This process for fabricating cermets includes ceramic and metal components and a molten-metal infiltration method. The lightweight cermets have improved porosity, strength, durability, toughness, and elasticity when fabricated from presintered ceramic powder infiltrated with a molten metal or metal alloy. Alumina titanium cermets are biocompatible with the human body and are suitable for bone and joint replacements.

Awards

Physicist **Kennedy Reed** was awarded the distinction of **Fellow** of the **American Association for the Advancement of Science** (AAAS), an honor bestowed on AAAS members by their peers. In naming him as a fellow, the association honored Reed for important studies in atomic theory and for many successful efforts to increase minority participation in the physical sciences in the U.S. and Africa. Reed has produced more than 100 publications on his research in atomic collisions in high-temperature plasmas, and his work has contributed to the understanding of indirect processes in electron-impact excitation and ionization of highly charged ions. He is a prominent leader in national efforts to increase opportunities for minority students and professionals in the sciences.

A team of Livermore scientists led by **Monica Borucki**, along with Sharon Messenger from the California Department of Public Health, won an **outstanding poster award** at a **Defense Threat Reduction Agency** conference in November 2010. Other Livermore scientists on the team include **Jonathan Allen**, **Clinton Torres**, and **Tom Slezak**. Their work seeks to understand how a virus changes at the population level as it adapts from one host to another. The ultimate goal is to determine the probability of a specific animal virus jumping from animals to humans. "Understanding the evolution of RNA viruses is a major scientific problem that is essential for developing a better biodefense," says Borucki.

Cliff Chen of the Laboratory's Jupiter Laser Facility received the **Luis Alvarez Award** for "best experimental research by a postdoc" from the **American Physical Society** at the California–Nevada section's 2010 annual meeting. The facility's Titan laser is an important tool in the quest to investigate several key parameters for fast ignition. Chen's efforts were detailed in a presentation entitled "Bremsstrahlung Measurements of the Properties of Laser-Generated Hot Electrons for Fast Ignition." Current research suggests fast ignition may offer certain advantages, such as higher energy gain compared with indirect drive, more robust ignition, and lower-energy compression lasers and, thus, may lead to smaller-sized facilities.

The **National Nuclear Security Administration** (NNSA) Defense Programs announced in February 2011 the recipients of the **Defense Programs' Employee of the Quarter Awards**. The awards recognize individuals who have gone beyond the call of duty in supporting the mission of NNSA's Defense Programs.

"NNSA Defense Programs is fortunate to have dedicated men and women throughout the enterprise who are truly leaders in their fields working to promote our nuclear security agenda," said Don Cook, NNSA's deputy administrator for Defense Programs. "The work done by the recipients of these awards is a reflection on how NNSA is working to improve the way we manage our resources, including major projects, and our infrastructure."

The selection of the recipients is determined at each site following its own specific criteria. At Lawrence Livermore, **Aaron Puzder** was recognized for his work on the first hydrotest at the Dual-Axis Radiographic Hydrodynamics Test Facility, which was fired in the summer of 2010. **Mark Zulim** of the Livermore Site Office was recognized for providing oversight of all facilities and infrastructure at the Laboratory. In all, 16 employees received the quarterly award.

The Laboratory in the News (*continued from p. 2*)

applied x-ray diffraction to determine the high-pressure variation of the cerium structure and volume.

The team's results for the first time reveal cerium's equation of state near the critical temperature in the scaling theory framework of the liquid–gas transition that occurs in classical systems. Says Moore, "The work represents a step forward in achieving a reliable and unambiguous picture on the mechanism of phase transformation in cerium, an archetypal element of the localization–delocalization phenomenon encountered in f-electron systems, such as plutonium." Their research appeared in the February 11, 2011, edition of *Physical Review Letters.*
Contact: Dan Farber (925) 424-2256 (farber2@llnl.gov).

Cornstarch Could Plug a Spewing Oil Well

Livermore's Peter Beiersdorfer, Edward Magee, and David Layne, along with Washington University's Jonathan Katz, studied a new "top-kill" procedure for plugging a spewing oil well. Their research, funded by the Laboratory Directed Research and Development Program, suggests that a substance more like quicksand and less like ketchup could improve the top-kill method of plugging a blown-out oil well.

The new top-kill method involves overcoming a form of turbulence, which physicists call the Kelvin–Helmholtz instability. This instability can occur whenever two fluids move past one another at different speeds. For example, when wind blows over water, the instability manifests itself in the form of waves on the surface of the water. If the wind is strong enough, the waves then break up into tiny water droplets, which are blown away by the wind. The instability also occurs when a heavier liquid such as drilling mud is poured into a lighter liquid such as crude oil. The goal is to create a liquid that resists the instability by becoming thicker and even hard like a solid under stress, but otherwise flows like a thin fluid.

The research team created such a liquid using ordinary cornstarch. Then in a series of experiments at Livermore, they injected the cornstarch mixture into a 1.5-meter cylinder of oil at speeds comparable to those used in the top-kill procedure on the Macondo well in the Gulf of Mexico in 2010. The results, published in the January 31, 2010, issue of *Physical Review Letters,* showed that the cornstarch formula descended down the oil column without breaking up into droplets. Adding a shear thickening agent such as cornstarch may work as a top-kill procedure to plug a gushing oil well in the future.
Contact: Peter Beiersdorfer (925) 423-3985 (beiersdorfer1@llnl.gov).

Abstract

From Video to Knowledge

Persistics is an innovative data-processing "pipeline" designed to help the Department of Defense and other agencies monitor tens of square kilometers of terrain from the skies. The software's algorithms detect in real time potentially important events in streaming video data, thereby providing early warning of a threat and greatly strengthening tactical combat support. In addition to real-time monitoring, Persistics can also be used in forensic analyses of past events. The system first stabilizes incoming video imagery through extremely accurate calibration of onboard cameras and correction of pixel-to-pixel intensity variations. In this way, a mosaic made from hundreds of individual sensors can be represented as an image from a single camera. Persistics retains the level of detail necessary for detecting anomalies, while at the same time compressing the unchanging background by 1,000 times without losing pertinent information. This advance allows the system to tease out movers (people and vehicles) from the static background. Although the current Persistics configuration is designed for ground-station processing, Livermore researchers are working to shrink the size, weight, and power requirements to permit the system to be mounted onboard surveillance craft.
Contact: Sheila Vaidya (925) 423-5428 (vaidya1@llnl.gov).

Postdocs Energize Science
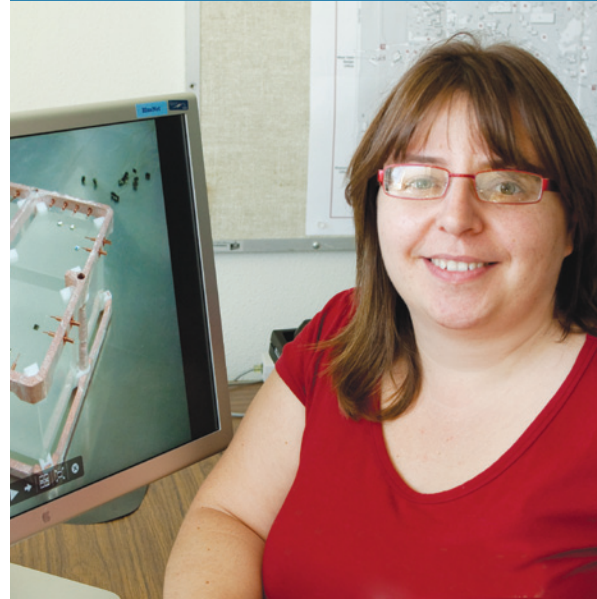
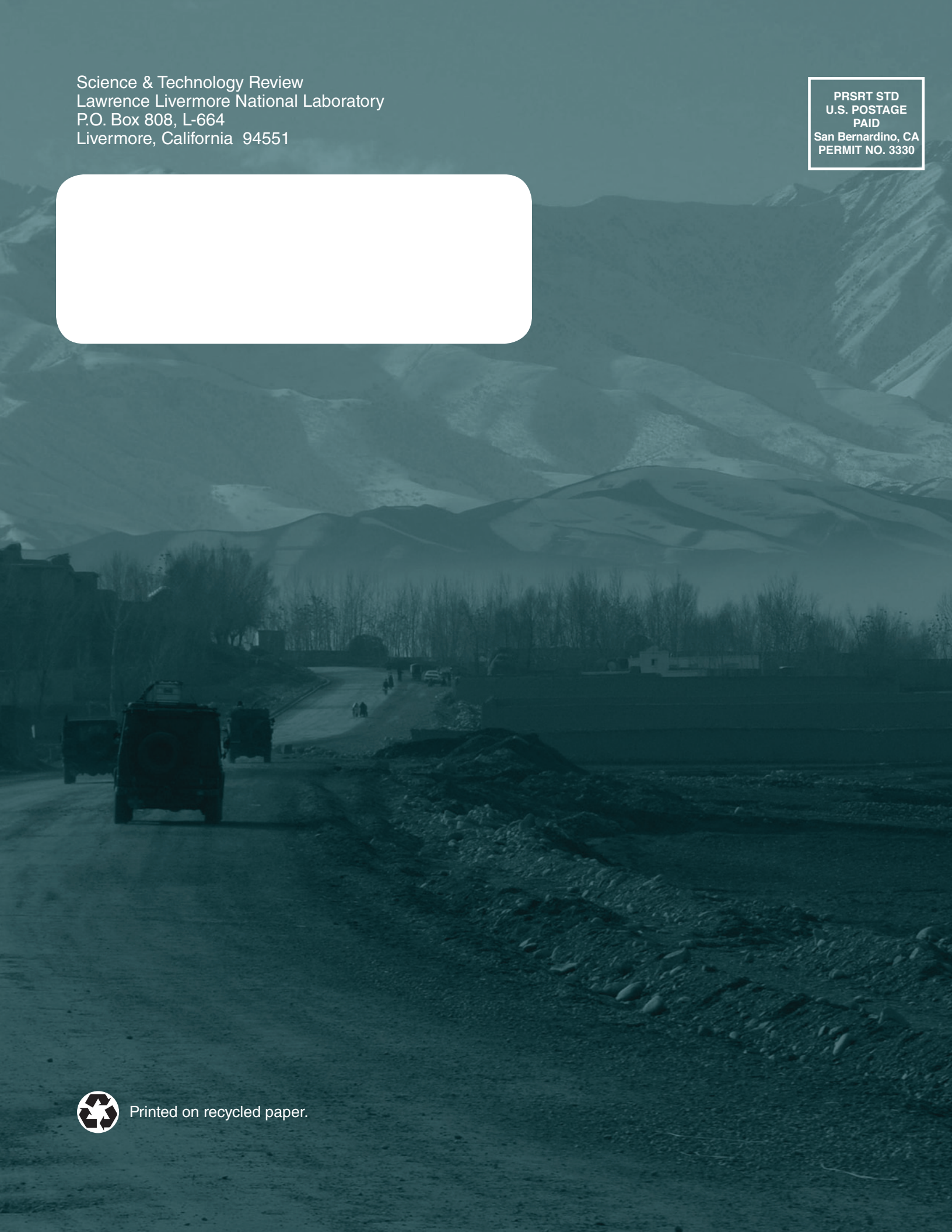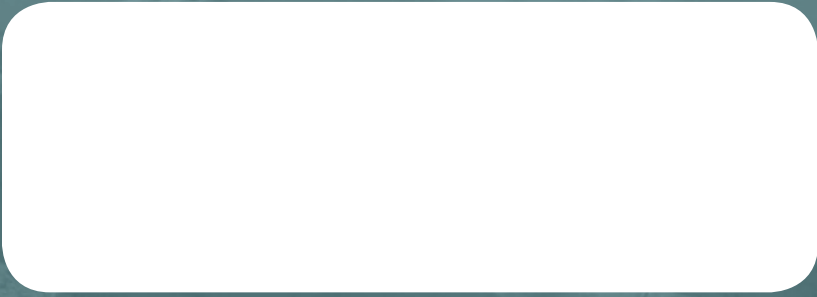Postdoctoral researchers bring passion and scientific expertise to Livermore research programs.

Also in June

• Low-angle comets striking Earth could have created the first amino acids, the building blocks of proteins and all life.

• A multidisciplinary team at Livermore looks to model and fabricate a new ribbonlike fiber for reliable, efficient laser light.

• A computed tomography technique to improve aviation security will detect a broad range of explosives.

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