September 2001

Science & Technology REVIEW

U.S. Department of Energy's
Lawrence Livermore
National Laboratory

Award-Winning Science and Technology

2001 R&D 100 Awards

Also in this issue:

- **National Security Implications of Technological Advances**

About the Cover

Once again, the science and technology done at Lawrence Livermore have won coveted R&D 100 Awards. Sponsored each year by *R&D Magazine*, these awards honor the "100 most technologically significant new products and processes" developed during the year. Since 1978, the Laboratory has won 85 of these awards. Livermore's three 2001 winners are depicted on the cover, each with a member of its research and development team. The winning inventions are (clockwise from the top) Lasershot Marking System (Hao-Lin Chen), Gene Recovery Microdissection (James Tucker), and Manufacturing Laser Glass by Continuous Melting (Paul Ehrmann). Turn to p. 4 for the details about these award-winning inventions.

Cover design: Kitty Tinsley

About the Review

Lawrence Livermore National Laboratory is operated by the University of California for the Department of Energy's National Nuclear Security Administration. At Livermore, we focus science and technology on assuring 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 10 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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Contents

R&D 100 Award Highlights

Feature

Departments

S&TR Staff

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Lab science, operations rated excellent

The Laboratory maintained an overall annual performance rating of "excellent" from the Department of Energy and showed significant improvement in scores for the National Ignition Facility, Laboratory Management, and Safeguards and Security.

The Fiscal Year 2000 assessment (October 1999 through September 2000) covers Livermore's performance in science and technology as well as administration and operations. This comprehensive evaluation system, along with annually negotiated performance standards, is defined in the University of California's contract with DOE.

Livermore scored 89.6 percent in science and technology and 89.9 percent in administration and operations, for an overall rating of 89.8 percent. Both scores constitute "excellent" ratings and represent increases over last year's totals. The science and technology score is just shy of 1998's science and technology score of 90.6 percent that earned the Laboratory an "outstanding."

According to Jeff Wadsworth, deputy director for Science and Technology, "The Laboratory continues to prove that it's a national leader in science and technology. These scores reflect the great progress we're making in meeting the rapidly evolving challenges of the Laboratory's national security missions. In particular, we are pleased with the significant improvement in the grade for the National Ignition Facility, which reflects DOE's confidence in NIF management and the progress made in its construction and design."

For John Gilpin, director of Contract Management, the score for administration and operations is the highest since the rating system went into effect in 1992. "These scores demonstrate the Laboratory-wide commitment to performance improvement and how our partnership with DOE and UC continues to meet management challenges of the last couple of years."

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Collaboration succeeds with plutonium container

The Laboratory has moved significantly closer to shipping its surplus plutonium to long-term storage off site, thanks to a collaboration between researchers from Livermore's Nuclear Materials Technology Program (NMTP), several of the Department of Energy's National Nuclear Security Administration facilities, DOE environmental management facilities, and British Nuclear Fuels Limited.

In late May, Livermore researchers produced the first container that meets all DOE and Savannah River Site (SRS) requirements for shipping plutonium to SRS in South Carolina, where it will be reprocessed and packaged for long-term storage. Plutonium was placed inside the innermost part of a three-part, nested container. The outermost container was welded shut using a laser welding system developed by British Nuclear Fuels Limited of Denver, Colorado. The Laboratory is the first among the sites that produce or store plutonium to accomplish this task.

"This is a tremendous example of what a good working relationship can accomplish," says Joe Sefcik, program leader for NMTP. "Through this process, we will be able to move surplus plutonium that we just don't need to have here."

Over the past two years, the NMTP team has worked to install a British Nuclear Fuels Limited Plutonium Packaging System in the Superblock of Livermore's Plutonium Facility. The team is also working to qualify the system to meet DOE Standard 3013 and a separate list of SRS requirements that would allow the Laboratory to "can" surplus plutonium for shipment and long-term safe storage. The Laboratory expects to begin shipping cans later this year.

At SRS, the plutonium will eventually be removed from the cans and either immobilized for safe underground disposal or converted into mixed oxide fuel for nuclear reactors.

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Boning up on calcite crystal growth

The June 14 issue of *Nature* includes an article on the process used by biological organisms to modify crystal shape and growth to form complex structures such as bones, eggshells, and seashells.

"Formation of Chiral Morphologies through Selective Binding of Amino Acids to Calcite Surface Steps" details the research and discoveries of a team of Livermore physicists, chemists, and geologists working in collaboration with the University of South Alabama and Virginia Polytechnic Institute and State University.

Livermore scientist Christine Orme, the article's lead author, explains that calcite, the material in eggshells and seashells, is perfect for studying biomineralization, the organic growth of crystalline structures. "Pure calcite grows only in a symmetrical, six-sided, pyramid-shaped crystal," says Orme. "We've wondered how nature controls the growth of the same substance to produce the intricate shapes found in shells and sea urchin spines. Now, by binding calcite with the amino acid aspartate, a common amino acid found in the protein of shellfish, we've been able to skew the growth to form asymmetric crystals."

Using the Laboratory's atomic microscopes, the team measured at the atomic level the speed and other variables of crystal growth in the calcite–aspartate. Surface spectroscopy and molecular modeling confirmed the visual results.

The team's research has myriad applications, from growing bones in the laboratory to studying scale formation in pipes to manufacturing toothpaste—any situation in which calcium-based crystals grow naturally or are used.

The team is extending its research to calcium phosphate, the material used by animals to grow bones. According to Orme, if bones are ever to be grown in the laboratory, these are the first steps in that process.

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Technology Transfer Takes a Team

A new method for making laser glass. A way to isolate expressed genes in DNA. Laser pulses to mark metal parts. Developing these inventions took a team of people from within the Laboratory or made up of Livermore scientists and engineers working with industrial partners. *R&D Magazine* recently honored these inventions with R&D 100 Awards. The products of Livermore research have received one or more of these coveted awards almost every year since the competition began in 1978. To date, Livermore has won 85 R&D 100 Awards.

Almost all scientific advances at Livermore are the result of multidisciplinary teamwork. Physicists, materials scientists, microbiologists, engineers, and others pool their varied talents to solve problems related to the Laboratory's mission. This multidisciplinary approach, this confluence of many kinds of expertise, is what makes a laboratory like Livermore a special place to do research.

Gene Recovery Microdissection was developed at Livermore by biomedical experts as a way to identify cancer genes in chromosomal regions for which there was no genomic information. The developers envisioned other possibilities for the process. Once it has been commercialized, Gene Recovery Microdissection will likely benefit research in toxicology, veterinary science, agriculture, and environmental science.

Sometimes finding solutions requires help from a commercial partner. The development of a faster, less costly technique for making high-quality laser glass for the National Ignition Facility is a case in point. It resulted from an alliance with Schott Glass Technologies of Duryea, Pennsylvania, and Hoya Corporation USA of Fremont, California, the two leading laser glass producers internationally. Not only will this process benefit the National Ignition Facility, but it will also benefit these industrial partners with a technology that is a springboard to new glass products.

Metal Improvement Company, Inc., worked with Livermore scientists to refine laser peening, a process developed earlier at the Laboratory for strengthening metal. Together, they created the Lasershot Marking System. A number of firms are already interested in using this permanent identification mark on their products.

When an industrial partner joins a Laboratory team, the focus of the effort extends beyond the scientific research to the needs of the business sector. Ultimately, when an invention is ready for full commercialization, Livermore's patent attorneys and other experts in transferring intellectual property join the team.

As Laboratory general counsel, I typically get involved in the technology transfer process both before and as it occurs. Also, as associate director for Administration, I am responsible for the Industrial Partnerships and Commercialization Office, which manages the transfer of technology from the Laboratory to the private sector.

The concept of technology transfer is relatively new in the federal sector. Its purpose is to take processes developed for a federally funded project and apply them to the needs of the private sector.

Even after a technology transfer team is fully formed—with scientists, business people, and intellectual property experts at the table—commercialization of a Laboratory invention does not happen overnight. It takes time for a new technology to mature. The three inventions that won R&D 100 Awards this year are still in their infancy. As they mature, Livermore scientists may continue to be involved with follow-on research to improve them. The business community is well aware of the skills resident at Livermore. Laboratory scientists and engineers are often the only ones with the expertise to evaluate and resolve technological difficulties that arise.

Since its inception, this Laboratory has taken a multidisciplinary approach to solving problems. Technology transfer is a more recent development, but it plays off that approach well. Teamwork among researchers and business people—and attorneys—is key to assuring that Livermore's scientific advances find their way to the private sector successfully.

■ Laboratory Counsel Jan Tulk is associate director for Administration.

Zeroing In on Genes

ALMOST every cell in the human body contains the same set of genes. But not all of the genes are used, or expressed, by those cells. For example, some processes that are particular to cells in the liver are completely unused in brain cells. Ever since genomic research began, scientists have been searching the tangle of DNA for the expressed genes, the ones that really matter.

If one thinks of the nucleus of a cell as a library, then the chromosomes in the cell are bookshelves and the genes are the books on each shelf. Almost every cell in an organism contains the same libraries and the same sets of books. The books represent all of the information (the DNA) that every cell in the body needs so that it can grow and carry out its various functions. Two challenges complicate the process of locating our genes: Not all of the genes are expressed in any one tissue, and less than 10 percent of our DNA is actually used to make genes. Only occasional passages in the library's written material are important.

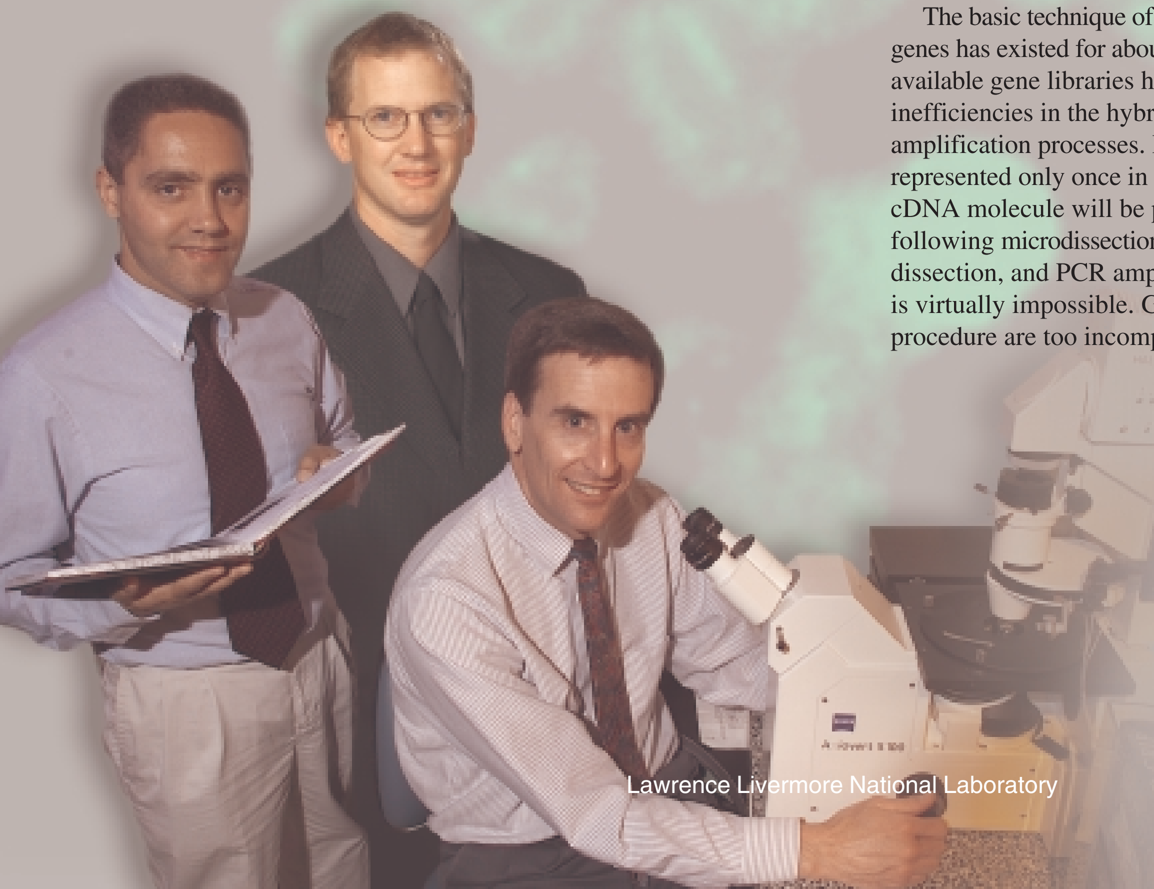
A team at Livermore led by molecular biologist Allen Christian has developed Gene Recovery Microdissection (GRM), a process that can weed out the unexpressed genetic material from a piece of DNA. With GRM, scientists can isolate all of the genes in a chromosomal region that are being used by a specific tissue at any point in time. GRM can be used for any plant or animal species. A variant of this method can also be used to clone all of the DNA of any organism, including bacteria, even those that cannot be cultured.

"It's not always necessary to sequence the entire genome of a species to locate its gene," says Christian. "With GRM, we can focus on particular regions of a genome that are of interest."

Amplification Twice Does the Trick

The product of gene expression is messenger RNA (ribonucleic acid), or mRNA. Typically, before work begins to isolate expressed genes, the mRNA molecules are converted into more stable complementary DNA molecules called cDNA, which has exactly the same sequence as the mRNA but is easier to handle in the laboratory. Then the cDNA is combined on a microscope slide with chromosomes. The cDNA molecules hybridize to the chromosome regions corresponding to the genes of which their parent mRNA is a product. Using tiny glass needles and microdissection, scientists can isolate regions of the chromosomes of interest and, with them, the hybridized cDNA molecules. Finally, amplification by polymerase chain reaction (PCR) is used to produce many copies of the molecules in preparation for DNA sequencing.

The basic technique of using microdissection to isolate genes has existed for about five years. But no commercially available gene libraries have been generated because of inefficiencies in the hybridization and subsequent PCR amplification processes. Because genes are typically represented only once in a chromosome, a maximum of one cDNA molecule will be present for each expressed gene following microdissection. Successful hybridization, dissection, and PCR amplification of a single molecule is virtually impossible. Gene libraries made with this procedure are too incomplete to be useful.



Developers of the award-winning Gene Recovery Microdissection process are (left to right) Matthew Coleman, Allen Christian, and James Tucker of Livermore's Biology and Biotechnology Research Program Directorate.

Livermore's GRM process overcomes this inefficiency by combining cytogenetics and genomics with chromosome microdissection. CRM increases both the number of targets available for cDNA hybridization and the total number of cDNA molecules in each region following hybridization.

The trick is to perform PCR amplification in situ, on the slide rather than in a tube, which is the conventional means. And it occurs twice. First, prior to hybridization, random-primed PCR of the chromosomes on the slide produces many copies of the target DNA, significantly improving the chances of cDNA hybridization. Second, following the hybridization, another PCR amplification using primers specific for the ends of the cDNA molecules increases the numbers of bound cDNA molecules. Instead of isolating just one cDNA molecule per expressed gene in a region, the GRM process recovers hundreds or even thousands of cDNA molecules. This simple step makes possible the production of highly useful chromosome-region-specific libraries.

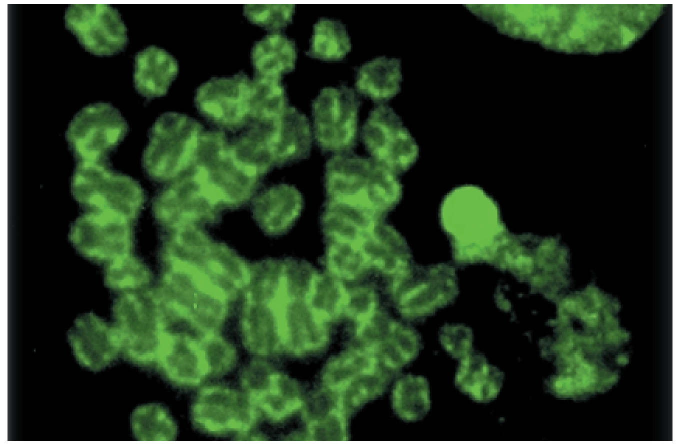
GRM has other advantages. While cells generally contain only one or two copies of a gene, some genes make thousands of copies of mRNA and others make only a few copies. Finding mRNA molecules with a low number of copies amid the "noise" of the more numerous gene products can be difficult with conventional methods of making cDNA libraries. But the hybridization step in GRM results in a balanced library in which mRNA molecules with high and low numbers of copies are equally represented.

Several companies offer processes that provide partial information about gene expression and genomic location. But no other single technique identifies both known and unknown expressed genes and determines the part of the genome that regulates their expression. GRM makes possible in one process what multiple processes could previously handle only in part, and it does so cost effectively. Current estimates are that the costs associated with GRM will be substantially less than those of traditional methods. The process is also significantly faster.

Benefits Abound

GRM was invented to allow researchers to identify cancer genes in chromosomal regions for which no genomic information existed. Initially, these were regions for which scientists had good evidence of their importance in rat mammary cancer but almost no other knowledge. To identify the genes expressed in these regions, researchers needed a quick, simple, inexpensive, and reliable method of identifying and characterizing both new and previously known genes in chromosomes.

GRM focuses on data that current genomic sequencing efforts do not provide, namely, information concerning the expression of genes in specific regions of abnormal cells, such as those found in cancerous tissue. "We are using GRM to learn which genes are expressed in certain parts of chromosomes in cancer cells," says Christian. "We can then compare our data with data from the Human Genome Project and learn how these particular cancer cells differ from normal cells."



Chromosomes amplified by Gene Recovery Microdissection. Amplification is by polymerase chain reaction and produces many copies of stable complementary DNA molecules in preparation for sequencing.

GRM will be used to generate chromosome-specific and chromosome-region-specific libraries of genes that are expressed for any tissue, normal or diseased, of any organism that can have its chromosomes spread on a microscope slide. Once these libraries have been produced, they can easily be placed on microarrays and made available to other investigators for more detailed analyses, including gene expression studies. GRM can thus be used to create a systematic approach to identifying genes expressed in virtually every species of interest to humans. This capability opens the door to sequencing many plant and animal species that might otherwise be ignored because of the prohibitive cost of genomic analysis. Agriculture, environmental sciences, and veterinary medicine will all benefit.

GRM technology provides the preliminary step toward a full genomic analysis of an organism, allowing time and money to be saved during the full analysis. This invention will enable scientists to identify genes that are expressed after exposure to drugs, environmental chemicals, or radiation. Toxicologists can study the reactions of cells and organisms to chemical and radiation exposure, furthering basic understanding of the molecular mechanisms involved in responses to adverse environments. Similarly, the pharmaceutical industry will be able to decipher biological responses to drugs.

—Katie Walter

Key Words: Gene Recovery Microdissection (GRM), genomic research, R&D 100 Award.

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Big Glass for a Big Laser

THE National Ignition Facility (NIF), the largest, most energetic laser in the world—with 60 times more energy than any laser in existence—will be coming on line at Livermore in the next few years. In this laser, energy will be stored in special glass and later extracted as high-power optical pulses. High-energy lasers such as NIF need large pieces of optical-quality glass—and lots of them—to operate as designed. NIF will be about the size of a football stadium and will require more than 3,000 pieces of laser glass, each about 1 meter long, 0.5 meter wide, and 4 centimeters thick.

A revolutionary process developed by Lawrence Livermore and two industrial partners produces meter-size plates of laser glass at a rate 20 times faster and 5 times cheaper than is possible with the previous technology, and the glass itself has 2 to 3 times better optical quality. This work is the culmination of a 6-year research and development project between Livermore and the two leading (and competing) laser glass producers, Schott Glass Technologies of Duryea, Pennsylvania, and Hoya Corporation USA of Fremont, California. Physical chemist Jack Campbell of Livermore led this team.

The Continuous Laser Glass Melting Process developed by the collaboration replaces the only other way to manufacture large pieces of laser glass—the batch method, a one-at-a-time process that produces at most three pieces of glass per week. Not only is this method too slow to meet the demands of NIF, but it is also more expensive, and the optical quality of the glass is not consistent. Practically speaking, continuous glass melting is the only method that can be used to produce the large quantity and high quality of laser glass necessary for NIF. Without this technology, it would be extremely difficult to build a huge solid-state laser such as NIF.

"Developing this process was extremely difficult technically," says Campbell. "In fact, we had a saying, 'laser glass knows no friends,' to describe our frustrations. Now that the process has worked out successfully, frustration has given way to pride. But believe me, there were many anxious moments."

A River of Glass

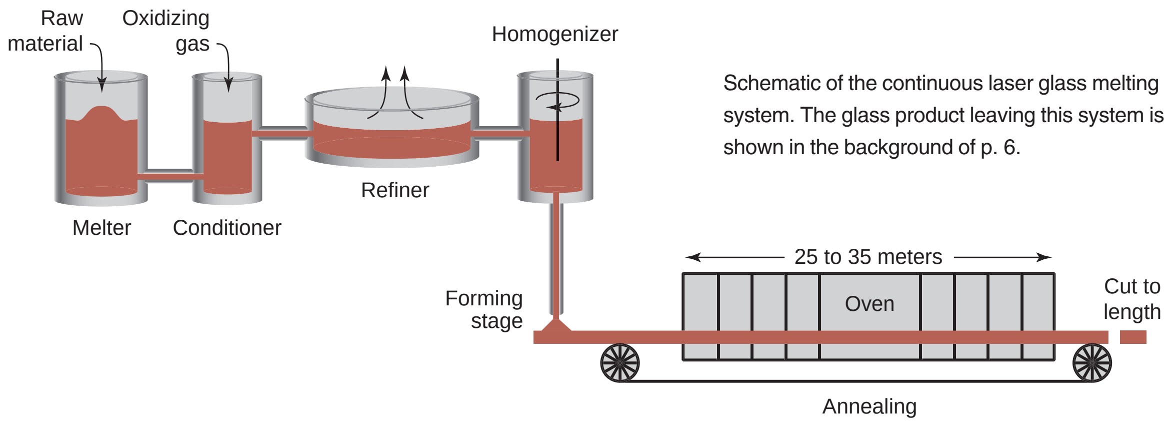
The Continuous Laser Glass Melting Process, shown schematically on the next page, converts high-purity, powdered raw materials into one continuously moving strip of high-optical-quality laser glass. Plates of laser glass are then cut from the end of the strip as it leaves the production system.

The laser glass melting process requires seven operations carried out in separate vessels. The vessels are interconnected to make the process continuous. The first process unit is designed to mix and dry the high-purity raw materials with minimal contamination.

The second unit is the melter system, which dissolves the powdered raw materials into a pool of molten glass and mixes these ingredients using convection currents.The melter consists of custom-designed, high-purity refractory materials and uses a proprietary electrical heating system.

All units beyond the melter are lined with high-purity platinum, as are the interconnecting pipes. Platinum is required to achieve the fine-scale (parts-per-million) optical homogeneity necessary

Livermore developers of the Continuous Laser Glass Melting Process are (left to right) Paul Ehrmann, William Steele, Charles Thorsness, Michael Riley, Tayyab Suratwala, and Jack Campbell. The system was developed in partnership with Koji Suzuki, Kohei Yamamoto, Ryo Konta, Kunio Takeuchi, and Julie Storms of Hoya Corporation USA and Steve Krenitsky, Joe Cimino, Hardy Pankratz, Michael Timms, Dave Sapak, Ed Vozenilek, Joseph Hayden, and Alfred Thorne of Schott Glass Technologies.



Schematic of the continuous laser glass melting system. The glass product leaving this system is shown in the background of p. 6.

for laser applications. However, the platinum can contaminate the glass with microscopic metallic inclusions. When a high-power laser beam hits an inclusion, the beam causes it to vaporize, generating small fractures within the glass. To overcome this problem, the team developed a unique conditioner unit that uses oxygen and chlorine to remove platinum inclusions as well as any residual water. The conditioner unit is perhaps the most complex part in the whole system.

The glass from the conditioner next moves to a refiner section, where bubbles are removed using a combination of high temperature and proprietary additives. From here, the glass enters the homogenizing unit, where it is thoroughly mixed to achieve the one-part-per-million chemical uniformity required to meet optical homogeneity specifications. Finally, molten glass flows through a platinum tube to a mold, where it is formed into one continuously moving strip about 5 to 8 centimeters thick, 0.5 meter wide, and nearly 30 meters long. The glass strip passes through a custom-designed annealing oven where it is gradually cooled from more than 600°C to room temperature. Annealing the laser glass strip is difficult because of the size of the strip and the unusually high thermal expansion and low inherent strength of the glass. Laser glass is five times more sensitive to fracture by thermal shock than most other optical glasses.

Older Process Not Adequate

Neodymium-doped phosphate laser glass can be manufactured by either the batch method, a one-at-a-time melting process, or this new continuous melting method. Schott and Hoya are the only companies in the world making meter-size plates of phosphate laser glass, either by a continuous or discontinuous process. Thus, the only competitor for the new process is the old, discontinuous technology for producing laser glass.

The former technology, which has been used for over 25 years, involves first melting raw materials in a refractory vessel and then manually transferring the melt to a second platinum-lined vessel. Finally, the pieces of glass are individually cast in a large mold. The entire operation is repeated for every piece of glass. Product quality can vary from one melt to the next simply because of small, run-to-run variations in processing conditions. The cost—more than $5,000 per liter of glass—is also high.

Continuous glass melting, however, has a much greater production rate of 70 to 300 pieces per week, and little, if any, measurable variation in glass properties from one glass plate to the next. Plus, the cost is less than $1,000 per liter.

NIF and Beyond

Hoya and Schott will also be manufacturing large pieces of glass using the continuous melting method for the Laser Megajoule (LMJ) in France. The LMJ's requirements are similar to those of NIF.

Both Hoya and Schott are applying several new technologies developed for the Continuous Laser Glass Melting Process to the manufacture of other optical glasses. Most notably, some of this technology is being used to manufacture the most common optical glass, BK-7, in large sizes. BK-7 is commonly used to manufacture optics for cameras, binoculars, and precision optical instruments. Other aspects of the process are being used to improve the manufacture of glass used in digital cameras, hard-disk-drive substrates, liquid crystal displays, projector lenses, and telecommunication devices.

"The success of this venture is illustrated by the fact that neither company is willing to openly discuss the details of the other applications for the new technology," says Campbell. "The bottom line here is that everyone is a winner from this partnership. NIF gets the laser glass it needs, and our industrial partners get a technology that is a springboard to new glass products."

—Katie Walter

Key Words: Continuous Laser Glass Melting Process, National Ignition Facility (NIF), neodymium-doped phosphate laser glass, platinum inclusions, R&D 100 Award.

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Lasershot Makes Its Mark

ANYONE getting a hip replacement expects the implant to be certified and last a long time. The same goes for new and replacement parts in aircraft. The assumption is that critical parts—especially those used in applications where safety is paramount—are certified by the manufacturer and the government and are made to exact specifications. Lawrence Livermore and Metal Improvement Company, Inc., have developed a system that helps identify certified and other high-value parts.

The Lasershot Marking System imprints permanent, high-resolution identification marks that are difficult to counterfeit, readable by machine, and strengthen the part at the site of the mark, in contrast to other marking methods, which can actually weaken the part. “Before Lasershot, there was no way to permanently mark parts used in safety-critical applications without inducing the danger of fatigue and stress-crack corrosion,” notes Livermore physicist Lloyd Hackel, primary developer of the system.

From Hip Implants to Space Stations

The Lasershot Marking System has the potential to be of great use not only to makers of medical and aircraft components, but also to aerospace organizations such as the National Aeronautics and Space Administration (NASA). It is a prime candidate for imprinting safety-critical parts with the Air Transport Association 2000 Data Matrix, a high-data-intensity, two-dimensional, machine-readable symbol recently adopted by NASA. NASA plans to use this data matrix to identify and track the millions of parts used in the space program. Currently, the matrix is imprinted on the thousands of heat-resistant tiles on the Space Shuttle using a traditional marking technique. However, safety-critical metal parts are not marked at all because of the risk of marking-induced failure. The invention of the Lasershot Marking System means that NASA may soon be able to mark and track these important parts as well.

NASA has added Lasershot marking to its *Data Matrix Direct Part Marking Standard and Handbook* and included three samples imprinted with the mark in its Materials International Space Station Experiment, which was launched on the STS-105 in August. The sample parts were bolted onto the space station to face the slipstream solar wind. After one year, they will be retrieved and examined to evaluate how well they held up in the hostile space environment. NASA and the Department of Defense are also conducting ground, flight, and in-orbit tests of laser-peened marks to certify Lasershot’s use in current and future programs.

Other organizations—the Air Transport Association, the Electronic Industry Association, the Automotive Industry Action Group, and the Semiconductor Equipment

Livermore developers of the Lasershot Marking System are (left to right) Brent Dane, Lloyd Hackel, Hao-Lin Chen, John Halpin, and John Honig. The system was developed in partnership with James Daly, Fritz Harris, Laurie Lane, and James Harrison of Metal Improvement Company, Inc.

Manufacturers' Institute—have chosen the Data Matrix standard as the preferred one for parts marking, thereby extending the potential applications for the Lasershot system. Components that could be marked with this method include fan blades, disks, rotors, and integrated rotor assemblies as well as components in automobiles.

A mark created by the Lasershot system allows manufacturers and users to positively identify each individual part and trace each part from manufacture to retirement. In addition, Lasershot peen marking will be a valuable tool in combating counterfeit parts by providing a unique, permanent, and difficult-to-reproduce tracking symbol, one that also strengthens the part at the site. The mark contains fine detail nearly impossible to counterfeit, much like the watermark on modern currency. Part counterfeiting is a growing concern. According to government estimates, as much as $2 billion in unapproved parts are now sitting on the shelves of parts distributors, airlines, and repair stations.

A Chip off the Laser Peening Block

Peening—a technique common in metalworking—uses a ball-peen hammer or pneumatically shot small metal balls to pound a piece of metal into shape and strengthen it against fatigue failure. Replace the hammer or metal balls with a laser and the blow of metal on metal with the pressure wave of a laser light pulse on metal, and laser peening results. (See *S&TR*, March 2001, pp. 26–28.)

In the Lasershot peen-marking process, a layer of absorptive material is placed over the area to be peened, and a thin layer of water is flowed over the absorption layer. A high-intensity laser with an energy density (fluence) of about 100 joules per square centimeter illuminates and ablates material from the absorption layer, creating an intense pressure pulse that is initially confined by the water. The absorption layer protects the part surface from material removal or melting. The pressure pulse creates a shock wave that strains the surface in a two-dimensional pattern that mirrors the laser's intensity profile. By creating the desired pattern upstream in the light and then imaging this pattern onto the metal, a complete mark can be made with a single laser pulse.

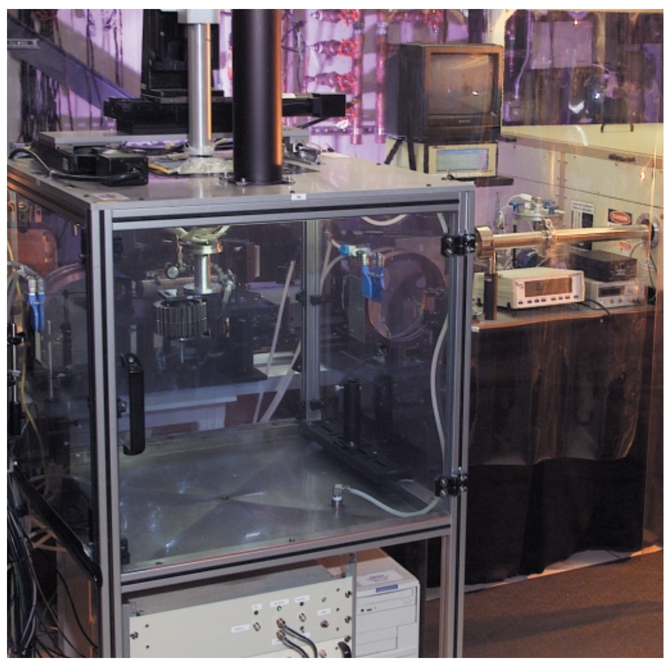
"The laser system projects the pattern on the part in much the same way that a slide projector creates an image on a screen," explains Hackel. "A slide projector without a slide in place projects a light field of uniform intensity on the screen. No image or pattern appears. When a slide is inserted between the projector bulb and lens, the light and dark areas of the slide provide an intensity profile pattern that is imaged onto the screen. With the Lasershot system, we use a laser and a special telescopic system to image the pattern of a mark onto the metal part. The laser fires, and that entire mark is printed on the part in a single pulse."

This single-pulse technique is well suited for high-volume marking applications. For low-volume use, a smaller system—the multiple-shot matrix marking system—builds up a two-dimensional mark using multiple laser pulses.

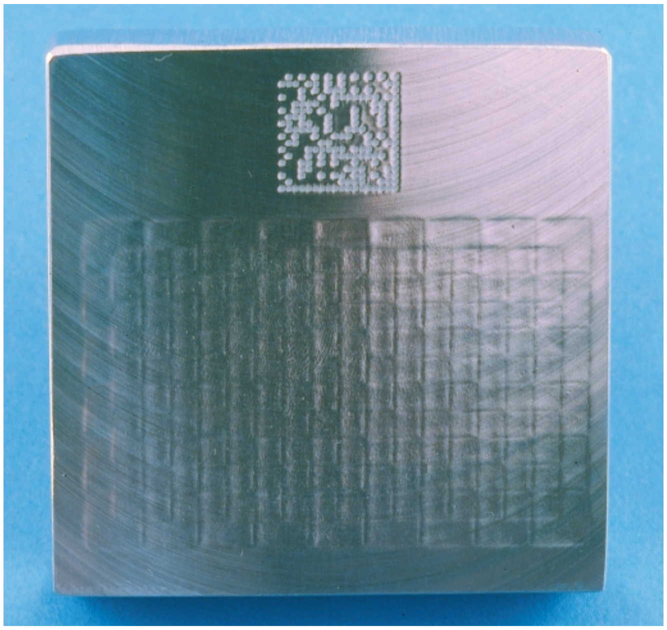
Technology Breakthroughs Make It Possible

The Lasershot technique was made possible by a patented breakthrough in laser technology developed at Livermore involving a neodymium-doped glass laser and a wavefront correction technology, called phase conjugation. "We can now build laser systems that operate up to six pulses per second, with output energy of greater than 25 joules," says Hackel. "This means we can peen-mark six data matrices per second, using the single-shot pattern marking technique." The phase conjugation provides a high-quality beam that has high, long-term pointing stability for the high repetition rates needed for the smaller multiple-shot marking system. As a result, the Lasershot system can mark parts at a rate comparable to or exceeding that of conventional marking methods.

The other key to the system is a specially designed and patented telescopic delivery system, which precisely relays



A Lasershot peen-marking station. The Lasershot Marking System (shown in action in the background of p. 8) uses laser pulses to safely and permanently impress identification markings on metal components without weakening them. The system is thus ideal for marking parts used in situations where safety is critical—from hip-joint replacements to commercial airliner components.



A 10- by 10-character identification mark—approximately 0.3 centimeter on a side—imprinted into an aviation-grade aluminum alloy using the Lasershot Marking System. Unlike other marking methods, Lasershot increases the marked area's resistance to fatigue and corrosion failure, and the resulting high-resolution mark is difficult to counterfeit.

the image onto the part surface. "This beam delivery is critical for accurately replicating a two-dimensional marking pattern," notes Hackel. "The resulting mark has uniquely embossed fine detail, making it nearly counterfeit-proof."

Mark Is Stronger, More Durable

Although other techniques are available for imprinting identification marks on metal parts, none measures up to the Lasershot method. The primary techniques are laser etching, pin stamping, and ink-jet printing. Laser etching systems work by focusing energy directly onto the surface to be marked and etching the surface with heat. The heat generated actually alters the part's surface, even vaporizing the surface in some cases. Although this technique has good permanence and generates a clear mark, it modifies the material. In steel, for instance, the high temperature causes carbon to precipitate out in the area hit by the laser beam, ultimately degrading the part's strength. The material modification and strength degradation can lead to fatigue or stress-corrosion crack failures. In a scanning electron micrograph study of 10 hip replacement implants that had failed much earlier than they should have, 5 of the 10 showed fatigue fractures that began in the characters that had been laser-etched on the implant surfaces. "These failures could have been prevented by the Lasershot method," notes Hackel.

In pin stamping, a conical stylus impacts the surface, with the size of the mark controlled by how deeply the stylus indents the metal. Like peening with a conventional ball-peen hammer, pin stamping may leave some residual compressive stress in the part, which would provide some protection against fatigue and mechanical stress. However, this method also roughens the surface and concentrates the stress at the bottom of the sharp indentations. In addition, pin stamping can distort small or thin parts.

Although marking using the ink-jet technique does not affect the surface material, the markings are not necessarily permanent. The permanence of the mark depends on the chemical interaction of ink and part as well as on the environment in which the part is used.

Sandblasting, machining or engraving, chemical etching, and welding also degrade strength and shorten the fatigue lifetime of metals. "Other techniques can cast symbols on parts during manufacturing," notes Hackel. "However, they only work for larger parts and don't address the need to mark parts already manufactured or those produced by noncasting methods such as forging and machining."

Unlike laser etching, Lasershot removes no material, and the marked surface remains chemically unaltered. Unlike pin-stamped marks, Lasershot does not roughen the surface. Plus the compressive layer from laser peening extends as deep as 1 millimeter into the metal, adding strength to this local area.

Mark the Future for Lasershot

The Lasershot Marking System allows manufacturers for the first time to safely and permanently mark and label metal parts used in situations where failure means big trouble. Donald L. Roxby, director of the Symbol Research Center, an international leader in the development of advanced symbology solutions for industrial, materials handling, and manufacturing environments, notes in a recent letter to Hackel, "Our organization was elated when we became aware of your work related to lasershot peening. The lasershot peening process provides the marking fidelity required to apply dense symbols to small parts without injecting risk. The process makes it possible to identify internal engine components such as aircraft turbine blades and a host of other difficult marking applications."

The R&D 100 Award judges voted their agreement. Lasershot is poised to make its mark in the world of safety-critical parts manufacturing.

—Ann Parker

Key Words: Lasershot Marking System, laser peening, R&D 100 Award, safety-critical metal parts and components.

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Tracking the Global Spread of Advanced Technologies

The Center for Global Security Research is examining how new technologies in the wrong hands could threaten national security.

GIVEN the pace of technological advancements and their rapid diffusion to the far corners of Earth, what might the world look like in 15 to 20 years? And what are the implications for America's national security and for its deterrence options? To answer those questions, Lawrence Livermore's Center for Global Security Research (CGSR) is sponsoring workshops involving some of the brightest minds in science and technology, government, and academia.

"Technology is spreading incredibly fast, and breakthroughs do not respect national borders," says geophysicist Eileen Vergino, CGSR deputy director. "We want to examine the national security risk from the spread of new

Vice Admiral Arthur Cebrowsi, president of the Naval War College, and George Shultz, former Secretary of State and currently a fellow at Stanford University's Hoover Institution, discuss national security threats posed by the globalization of advanced technologies.

technologies and decide if there are particular threats that the nation ought to be focusing on.” She explains that the CGSR workshops have not concentrated on response options to immediate threats; rather, they have focused on the more distant future 15 to 20 years away. (See box on p. 14.)

Vergino notes that as global tensions have relaxed, so have restrictions on the flow of commercial and military technologies. Military forces, including this nation’s, are turning to commercial electronic components to take advantage of industry’s rapid innovations and to hold down costs. Adversaries, too, have access to many of the same technologies that the U.S. relies on for conventional warfare, and therein lies one threat considered in CGSR workshops.

Last year, CGSR brought together different groups of experts to discuss likely technology-driven threats to the U.S. and its allies in the 2015 to 2020 timeframe. The series of workshops was entitled “After Globalization: Future Security in a Technology-Rich World.” About 100 participants gathered from other national laboratories, the Department of Defense, the National Aeronautics and Space Administration, Congress, the intelligence community, universities, think tanks, consulting firms, and private industry. In addition, about 40 Livermore scientists, with backgrounds ranging from molecular biology to global climate change, participated.

Participants at each workshop were asked to examine threats from nuclear, missile, and space technology; conventional military technology; information technology; biological technology; or geological systems technology. In December 2000, an Integration Workshop and Senior Review involving national leaders and experts was held to discuss the workshops’ findings. A top-flight panel was led by former Secretary of State George Shultz, who was introduced by CGSR director Ron Lehman as the “father of globalization.”

Spotting Troublesome Innovations

The “After Globalization” workshops were conceived and sponsored by CGSR Director Lehman and led by Livermore engineer and CGSR senior fellow Thomas Gilmartin. “The workshops focused on what we know, what we do not know or cannot agree on, and what is needed to resolve the unknowns,” says Gilmartin. “We took into account historic threats but emphasized potentially troublesome innovations in every technology area.”

Gilmartin says that developing threat responses was outside the project’s scope but might be the goal of follow-on projects. “We set this limit because a focus on response would limit the time and energy that participants spent on imagining a full range of possible threats. The discussion of threats and enabling technologies alone is a prodigious task.”

Participants noted that the Internet, migration, multinational corporations, and global research collaborations are all helping to give every nation as well as small extremist groups access to resources and technical knowledge. Participants also pointed to the importance of so-called dual-use technologies. For example, the same computer workstation used ostensibly for animation could be used for designing a nuclear warhead. Medical equipment supposedly purchased for making pharmaceuticals could be used instead to produce new strains of infectious microbes.

Much discussion focused on the globalization and proliferation of nuclear weapons as well as technologies that could sharply affect the cost of nuclear weapon development, production, and delivery. Such technologies include computers, nuclear materials enrichment, robotics, machining, cruise missiles, space launch vehicles, global positioning systems, and satellite imaging.

At the same time, advanced technologies for nonnuclear weapons are diffusing rapidly throughout the globe. The net effect is to provide future enemies with access to advanced equipment and technologies such as remotely guided weapons and stealth technologies—or at least the know-how to develop them. U.S. air and sea operations may thereby face smart

A number of threat sources, ranging from terrorist groups to emerging nations, are capable of accessing advanced technologies and know-how provided by corporations, the Internet, the black market, and other sources.

mines, quiet submarines, stealth planes, and advanced antiaircraft missiles.

Weapons containing advanced technologies are being manufactured and offered for sale by a growing number of nations. For example, a German propulsion frigate with stealth technology is being built for South Africa. India and other nations are developing hypersonic ramjet missiles. And Russia is marketing MIG fighter jets with state-of-the-art missiles.

Wide-Ranging Threats

In all, participants cited 45 possible threats covering a wide range of lethality and likelihood of occurrence and including more than 60 enabling technologies. Many of the threats were traditional, such as nuclear warfare. Other scenarios were more speculative—bordering on science fiction—yet quite possible in the future, given the pace of innovation and discovery.

The threats were ranked by risk, that is, the probability of their occurrence times the severity of their consequences. The top threats were judged to be nuclear weapons used in a terrorist attack; diseases, both natural and engineered; nuclear weapons used in a limited regional war; a major nuclear war; human control of future biological forms; a lessening of the dominance of U.S. conventional force; and gaining and losing control of nature. Asymmetry—taking advantage of gross differences in vulnerability, tactics, or values of one nation's military power over other nations'—and information operations were also discussed. (See box on p. 17.)

In ranking the threats, many participants felt that the potential danger of biological weapons of all types has been underestimated. Emerging and reemerging deadly diseases could be weaponized. Agricultural species could be attacked directly or infiltrated with subtle unhealthy genetic modifications to kill off a wheat crop or devastate livestock. Just the threat of such use (psycho-biological warfare) could cause fear, confusion, and poor public and governmental response.

Examples of global advanced weapon technology are evident in new generations of arms marketed by dozens of nations.

Likewise, the potential misuse of geophysical systems as weapons and threats has not received much publicity. These threats include, for example, deliberately fouling the environment with chemical poisons, flooding or desiccating areas with radioactive contaminants, disrupting natural weather cycles, destroying dams, and deliberately creating fires. Humans could even learn to start hurricanes by seeding the skies or initiate a tsunami by inducing an already weak continental shelf to slump.

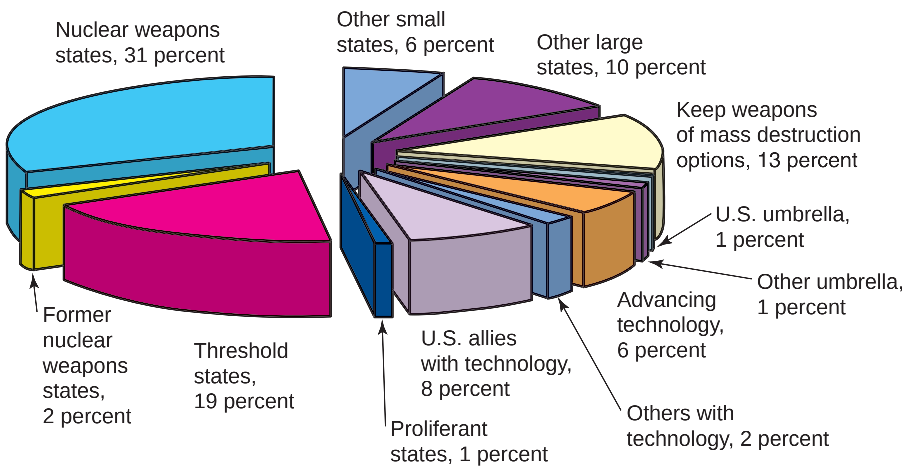
The class of threats called “unintended manmade” is particularly worrisome, Gilmartin says. This class includes the consequences of global warming and the long-term results from life-form modifications, biodiversity, and habitat loss. “Such threats might start as beneficial, but humankind has proven many times to have limited foresight when exercising its stewardship of nature,” he says.

In recent months, Gilmartin has presented papers on “After Globalization” at Stanford University and the University of California at Berkeley and at an international nonproliferation conference in Erice, Italy, thereby exposing an even wider international audience of scientists and policymakers to the methods and findings of these workshops.

Redefining Deterrence

A new CGSR project titled “Whither Deterrence?” is examining the future of deterrence in response to the new threat scenarios. “Whither Deterrence?” consists of exploratory workshops and a concluding conference at which participants will discuss new threat scenarios, conventional and nuclear weapon systems policies, and deterrence strategies.

The first “Whither Deterrence?” workshop was held in May 2001 in Washington, D.C., drawing participants primarily from academia, military agencies, and think tanks. The second workshop was held in June at Livermore and featured experts from the national laboratories. A number of Lawrence Livermore scientists took part who are expert on nuclear and biological technologies as well as deterrence policy. A final “Whither



Three of the top seven threats to U.S. national security involve nuclear weapons. The chart breaks down national nuclear weapons policy as a function of world population.

Center Provides Fresh Insight into National Security Issues

Founded in 1996, the Center for Global Security Research (CGSR) is an outreach effort of Lawrence Livermore National Laboratory that studies ways in which technology can enhance international security. “We probe issues at the intersection of technology and policy,” says CGSR deputy director Eileen Vergino.

Vergino notes that national and international security policy is inextricably linked with technology. The center aims to help policymakers understand the limitations and capabilities of science and technology while helping scientists understand policy. “We want to bridge the gulf between the two communities,” she says.

CGSR sponsors workshops, research fellows, and independent analyses. Projects typically join Lawrence Livermore scientists with other technical experts, academics, policymakers, military leaders, and industry executives. The result is fresh insight into some of the most vexing national security issues. (See *S&TR*, June 1998, pp. 10–16.)

While most projects focus on present international security concerns, other efforts such as the “After Globalization” and “Whither Deterrence?” workshops are focused beyond the next decade to help guide current U.S. actions and policy.

Vergino notes that although think tanks abound, few have such a concentration of experts in nuclear weapons, lasers, biotechnology, and other disciplines as Lawrence Livermore. CGSR, she says, is fortunate to be able to tap the expertise of Livermore scientists.

A number of well-known figures in technology and government have participated in CGSR workshops. During one CGSR event at Livermore in 1997, Attorney General Janet Reno announced the establishment of a new Federal Bureau of Investigation center to investigate attacks on the nation’s critical infrastructure. Other activities have included former Secretary of State George Shultz and Secretary of Defense Donald Rumsfeld.

Deterrence?" conference is scheduled for late November at Livermore, with a panel of distinguished national leaders and experts headed by Brent Scowcroft, national security advisor to former President Bush.

Carl Poppe, physicist and CGSR fellow, is leading the workshops. "The workshops are looking at what deterrence will mean 15 to 20 years from now," he says. For example, what role will nuclear weapons play? How should we deal with the emergence of new nuclear powers or nuclear alliances? Can traditional ideas of deterrence work in the face of new kinds of weapons?

He notes that the concept of deterrence, honed during the Cold War, focused primarily on the threats posed by Soviet nuclear weapons. With seeming suddenness, the Soviet Union split apart and the world moved from bipolar (East–West) to multipolar and factional. At the same time, the spread of new technologies around the world began to accelerate.

According to Poppe, "Today there are many more ways to exploit our vulnerabilities and many more players bent on acquiring the means to do us harm. During the Cold War, we were much more focused on the potential consequences of global war than on other serious threats that could arise and require well-thought-out deterrence measures."

Poppe cites new threats such as biological and chemical weapons and computer viruses and new threat initiators such as Iran, Iraq, Libya, North Korea, and terrorist groups. One challenge is deterring the use of biological and chemical weapons when the U.S. has foresworn the use of such agents.

Analyzing Future Threats

"After Globalization" and "Whither Deterrence?" are two of several projects that target policy and technology issues of importance in the next two decades. With such projects, CGSR carries on its tradition of sponsoring efforts to analyze long-range deterrence and proliferation issues. Among these is a recent project, which concluded at a workshop in April, that focused on one particularly worrisome example of nuclear proliferation: whether the 1994 agreement with North Korea, called the "Agreed Framework," can be verified. Under this agreement, the U.S. and its

In ranking threats to the U.S., many experts believe that the destructive potential of biological weapons has been underestimated. Lawrence Livermore scientists have been developing new methods to identify biological agents that could threaten urban populations, livestock, and crops.

Evolution of Thinking on U.S. Nuclear Deterrence Policy

The U.S. policy of nuclear deterrence has evolved since the end of World War II. What role nuclear weapons will play is being debated as old threats diminish and new threats emerge.

Year	Nuclear deterrence policy
1945	World war termination; countergenocide
1947	Sole nuclear power, component-based
1954	Massive retaliation, new-look army
1963	Flexible response, escalation dominance
1965	Assured destruction; damage limiting
1967	Mutual assured destruction
1969	Sufficiency; escalation control
1974	Essential equivalence
1976	Rough equivalence
1979	Presidential Directive 59; countervailing strategy
1981	National Security Defense Directive 13; peace through strength
1983	Strategic Defense Initiative
1989	Weapons of last resort
1994	Nuclear posture review
1997	Post–Cold War deterrent with hedge
2001	Deterrence, Assurance, Dissuasion, Defense
200?	Sustained deterrent? Flexible deterrent? Responsible hedge deterrent? Minimal deterrent? Recessed deterrent? Virtual deterrent? Undeterrence?
201?	Held in trust for humans?
2???	Reconstitution as a safeguard?

allies pledged to build two nuclear power reactors in North Korea and to provide fuel-oil shipments until the reactors were built. North Korea, in exchange, agreed to declare how much material it had produced for nuclear weapons, to stop producing the material at specific facilities, and to observe the Nuclear Non-Proliferation Treaty.

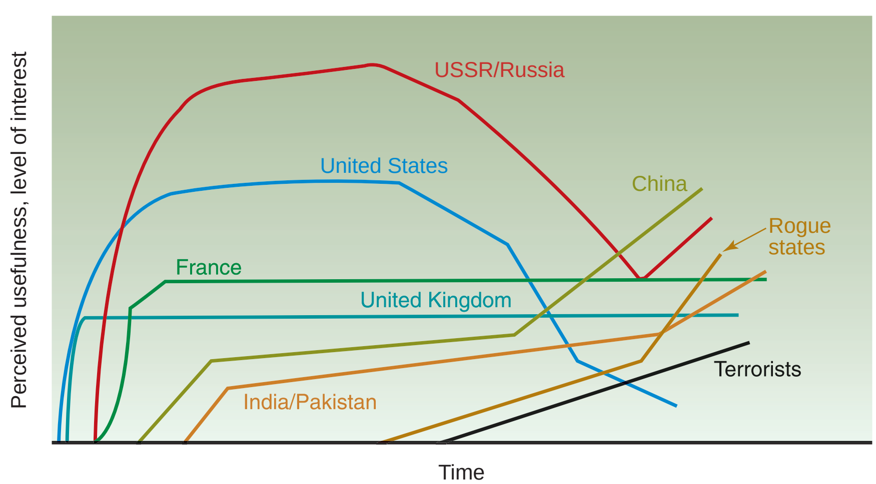
Former Secretary of Defense William J. Perry requested the verification study, which was conducted by CGSR and Stanford University's Center for International Security and Cooperation. Michael May, a former Livermore director, led the Stanford effort, and Lehman headed the Laboratory effort. Robert Schock, a CGSR senior fellow, says the report's bottom line is that the agreement with North Korea is verifiable, provided North Korea reveals the details of its weapons program.

Not only was this workshop timely, but it also got the attention of Congress and the current administration, helping them to understand the issues involved in verifying the 1994 agreement and to seek ways to speed up the verification process.

In January 2000, CGSR, together with the Institute for Strategic Studies in London, sponsored a conference titled "International Security Aspects of the Year 2000 Issue: Preliminary Assessments of What Really Happened and Lessons to Be Learned." The workshop was held at Livermore with people in London participating via videoconferencing. Attendees came from throughout the world.

In December 2000, the Center sponsored three days of discussion under the title "Beyond Moore's Law: Opportunities and Threats from Future, Ubiquitous High-Performance Computing." Representatives included personnel from the top U.S. computing and semiconductor companies, Department of Defense agencies, the Federal Bureau of Investigation, the Department of Energy, the National Security Agency, and other institutions.

CGSR and the Office of Engineering and Technology at the Federal Communications Commission (FCC) cosponsored the conference "Telecommunications Network Security and Reliability in the 21st Century" last October at FCC headquarters in Washington, D.C. Olivia Bosch, a CGSR fellow from the United Kingdom, led an effort by government, industry, and academic leaders to address major issues resulting from the rapid evolution of electronic communications technologies.



The perceived usefulness of nuclear weapons has changed significantly in recent years. It has declined for the U.S., but it has climbed sharply for other nations and terrorist groups.

In 1999, missile proliferation specialists convened for two days of discussion hosted by CGSR on the subject of "Missile Proliferation in a World of Rapidly Advancing Technology." The conference was, in part, a follow-up to the Congressionally mandated Commission to Assess the Ballistic Missile Threat to the United States, which released its report in July 1998. Donald Rumsfeld, now Secretary of Defense, headed the commission, which concluded that efforts by hostile or potentially hostile countries to acquire ballistic missiles pose a growing and largely underestimated threat to the U.S. and its allies.

Also in 1999, the Center held a workshop on "Proliferation-Resistant Nuclear Power Systems," at which a group of 90 international experts addressed the major questions and challenges surrounding the relationship between future nuclear power and the proliferation of nuclear materials for weapons and other means of nuclear terrorism. The focus was on the role that new technologies can play in enhancing the proliferation-resistance of civilian nuclear power systems. This workshop led directly to a Department of Energy study to recommend research and development in proliferation-resistance technology.

The report from this workshop was published in March 2000. The following June, Harold Feiveson of Princeton University cited the report in a conference paper at Stanford University, describing it as "an elegant overview of many of the proliferation-resistance concepts."

CGSR Influence Is Long Term

The effects and influence of CGSR projects and workshops are difficult to determine because they are frequently subtle and long term. For Vergino, the value of CGSR workshops lies more in the process than in the product. "The sessions are an enriching experience for both scientists and policymakers," says Vergino. "Because scientists don't focus

Possible Future Threats to the Nation

Major threats to the nation's security were identified and ranked by leading scientists and policymakers as part of "After Globalization" workshops. In order of highest risk (probability of occurrence times severity of consequences), the threats are assessed as follows:

Nuclear weapons in a terrorist attack. The danger that terrorists might use a crudely fashioned, purchased, or stolen nuclear weapon to attack a city has increased in recent years because of the proliferation of nuclear weapons and materials and the international increase in nuclear technology. At the same time, the rise of nuclear-enabling technologies, such as computing, robotics, and remote control, increase the probability that a terrorist could acquire and use a nuclear weapon. Such extreme terrorism might be viewed as useful to a number of organizations, especially those with nothing to lose. Attribution of such an attack could be difficult if the sponsoring group does not claim responsibility.

Natural and manufactured diseases. This threat has the potential for considerable misery and loss of life. Diseases considered to be eliminated or under control still exist in biological storage, persist in relatively isolated populations, or are reemerging in drug-resistant forms. Much of the once-immunized population is again vulnerable to smallpox, for example, and to antibiotic-resistant tuberculosis. In addition, new diseases are emerging, and biotechnology provides the means to modify and combine disease elements to tailor their effects. Some consider the means to design, manufacture, and disperse microbes for a biological attack relatively simple yet difficult to detect, and the knowledge of how to accomplish these ends is widespread. (See *S&TR*, May 2000, pp. 4–12.)

Limited regional nuclear war. Emerging nations cannot afford to deploy sophisticated systems of conventional arms. Nuclear weapons give a nation immediate dominance over its adversaries or at least "nuclear peerage," enormous deterrent capability, and significant stature among world powers. Nations possessing nuclear capabilities include Israel, India, Pakistan, Iraq, Iran, and North Korea, and others could acquire weapons over the next two decades. A situation could result in which one nation uses a nuclear weapon out of desperation, for vengeance, or to disable electrical devices. Such use of nuclear weapons might motivate other nations to acquire and use them, and the risk of nuclear conflict would be increased.

Major nuclear war. While the threat of global nuclear war has receded, large arsenals and delivery capabilities still exist. This threat ranks high not because of any current tension but because of the potential for catastrophe. Experts say that the current global situation is not like the East–West standoff that marked the Cold War. Rather, it resembles the multifaceted national relations that preceded World War I. Currently, several emerging nuclear nations, many of which harbor intense animosities, are involved in a complex web of alliances with each other and with established nuclear powers.

Human control of future biological forms. The threat from the malicious applications of biotechnology is widely discussed. However, new biological forms, developed out of the best of intentions, could have unexpected consequences. Through evolution, today's life forms have established complex interrelationships such that species are in equilibrium with their environments. Most future biological creations will serve specific purposes such as manufacturing medicines and organs for human use or seeds containing transplanted genes. These new biological forms will not be ecologically tested, and the dangers of unintended ecological and human disruptions could be significant.

Blunting of U.S. force projection. An array of new air defense and air combat technologies could diminish U.S. air dominance and capability and necessitate a new generation of strike and countermeasure technologies. The emerging technologies include sensors to defeat aircraft infrared countermeasures (for example, decoys that fool heat-seeking missiles), dome optics to give antiaircraft missiles greater speed and range, radar systems to lessen the effectiveness of stealth aircraft and antiradar missiles, visible-light sensors to lessen the effectiveness of cruise missiles, and improved infrared systems to increase the effectiveness of night operations. Also, stealth technology will likely become available for adversaries' aircraft, missiles, and ships, which will require greater protection for U.S. forces.

Gained and lost control of nature. Understanding weather, ocean currents, and geologic systems through computer simulation for long-term prediction—and possibly control—could generate new global threats. For example, one nation might understand how to generate a tsunami (giant tidal wave) by destroying an undersea continental shelf. In addition, human activities that add greenhouse gases are changing the weather in ways we cannot control. The effects of these changes, both beneficial and harmful, are quite varied. Their distribution among regions and nations, when better understood, is certain to be a source of international antagonism.

In addition to the seven major threats listed above, two others were cited:

Information attacks. U.S. computer systems are vulnerable in varying degrees, from simple intrusion and denial of services to coordinated, sophisticated attacks on financial activities, infrastructure, and military information. Last year, such attacks disabled Internet services and cost considerable amounts of money. These techniques could be used to design, control, and execute the listed threats, as well as to disrupt responses. However, at the Center for Global Security Research workshops discussed in the article, participants argued that defenses against information operations would evolve as needed and that such attacks by themselves would not destabilize the U.S. government, economy, or military.

Asymmetry. U.S. military dominance over other nations is an example of asymmetry. It is unlikely during the next two decades that any adversary will defeat us in conventional conflict. However, it is possible some group or nation, using a crude or breakthrough technology, could achieve asymmetry to its advantage. Participants agreed that such attacks would not seriously threaten the survival of the U.S. military or government but that determined adversaries could cause significant localized harm.

on policy, it's important for them to hear where policy is going and what its limitations are. At the same time, it's important for policymakers to hear where science is heading."

The center plans to examine the effects of new technologies in different ways. One effort under consideration is a series of workshops devoted to biotechnology and national security. In that light, a new fellow, a molecular biologist, will be joining CGSR. As with all CGSR projects, the overriding goal is not to achieve consensus but to clarify what U.S. national security experts know and what they need to learn about possible threats in the coming decades.

—*Arnie Heller*

Key Words: biological warfare, Center for Global Security Research (CGSR), globalization, nonproliferation, nuclear weapons, terrorism.

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The reports on the "After Globalization" and "North Korea and Nuclear Power" workshops can be found on the Web at cgsr.llnl.gov/global/global.html. For more information on the Center for Global Security Research and its work, see cgsr.llnl.gov/.

Above, a conference on lessons from the Y2K experience linked participants at Livermore and in London by videoconferencing. Workshops sponsored by Livermore's Center for Global Security Research often bring together participants from nations that are not on the friendliest of terms. At right, two experts from India and Pakistan confer at last year's Y2K workshop.

About the Scientist

EILEEN VERGINO is deputy director of Livermore's Center for Global Security Research (CGSR). She is responsible for helping to plan and implement CGSR studies, in particular those that examine how technology can enhance international security. She has primary responsibility for developing and implementing new collaborations between CGSR and academia, industry, and international government and nongovernment organizations and thus link Livermore science and technology expertise with outside policy expertise. She also has primary responsibility for community development activities with the city of Snezhinsk, Russia, as part of the Nuclear Cities Initiative. She serves on the Department of Energy's Community Development Task Force and was instrumental in establishing the sister-city relationship between Snezhinsk and Livermore.

Vergino, who has a B.S. in geophysics from the Massachusetts Institute of Technology, worked for over 16 years as a seismologist in Livermore's Treaty Verification Program on seismic yield estimation and discrimination studies. She is also the former director of Education Programs at Livermore and was responsible for creating and implementing regional and national education outreach programs for students and teachers from elementary school through graduate degree programs.

Each month in this space we report on the patents issued to and/or the 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.

Patents

Apparatus for Loading Shape Memory Gripper Mechanisms
Abraham P. Lee, William J. Benett, Daniel L. Schumann, Peter A. Krulevitch, Joseph P. Fitch
U.S. Patent 6,240,630 B1
June 5, 2001
A method and apparatus for loading deposit material, such as an embolic coil, into a shape-memory polymer (SMP) gripping and release mechanism. The apparatus enables the application of uniform pressure to secure a grip by the SMP mechanism on the deposit material via the differential pressure between, for example, vacuum within the SMP mechanism and hydrostatic water pressure on the exterior of the SMP mechanism. The SMP tubing material of the mechanism is heated to above the glass transformation temperature (T_g) while reshaping and is subsequently cooled to below T_g to freeze the shape. The heating or cooling may, for example, be provided by the same water applied for pressurization, or the heating can be applied by optical fibers attached to the SMP mechanism for directing, say, a laser beam to the tubing. At a point of use, the deposit material is released from the SMP mechanism by reheating the SMP material to above the T_g, thereby returning the material to its initial shape. The reheating of the shape-memory material may be carried out by injecting heated fluid (water) through an associated catheter or by sending laser light through optical fibers.

Apparatus and Method for Reducing Inductive Coupling between Levitation and Drive Coils within a Magnetic Propulsion System
Richard F. Post
U.S. Patent 6,250,230 B1
June 26, 2001
An apparatus and method for reducing inductive coupling between levitation and drive coils within a magnetic levitation system. A pole array has a magnetic field. A levitation coil is positioned so that in response to motion of the magnetic field of the pole array, a current is induced in the levitation coil. A first drive coil having a magnetic field coupled to drive the pole array also has a magnetic flux that induces a parasitic current in the levitation coil. A second drive coil having a magnetic field is positioned to attenuate the parasitic current in the levitation coil by canceling the magnetic flux of the first drive coil that induces the parasitic current. Steps in the method include generating a magnetic field with a pole array for levitating an object; inducing current in a levitation coil in response to motion of the magnetic field of the pole array; generating a magnetic field with a first drive coil for propelling the object; and generating a magnetic field with a second drive coil for attenuating effects of the magnetic field of the first drive coil on the current in the levitation coil.

Lamp System for Uniform Semiconductor Wafer Heating
Luis E. Zapata, Lloyd Hackel
U.S. Patent 6,252,203 B1
June 26, 2001
A lamp system with a soft, high-intensity output is provided over a large area by water cooling a long-arc lamp inside a diffuse reflector of polytetrafluorethylene and titanium dioxide white pigment. The water is kept clean and pure by a 1-micrometer particulate filter and an activated charcoal–ultraviolet irradiation system that circulates, deionizes, and biologically sterilizes the coolant water at all times, even when the long-arc lamp is off.

FALCON: Automated Optimization Method for Arbitrary Assessment Criteria
Tser-Yuan Yang, Edward I. Moses, Christine Hartmann-Siantar
U.S. Patent 6,260,005 B1
July 10, 2001
FALCON is a method for automatic multivariable optimization of arbitrary assessment criteria that can be applied to numerous fields where outcome simulation is combined with optimization and assessment criteria. A specific implementation of FALCON is for automatic radiation therapy treatment planning. In this application, FALCON implements dose calculations into the planning process and optimizes available beam delivery modifier parameters to determine the treatment plan that best meets clinical decision-making criteria. FALCON is described in the context of the optimization of external-beam radiation therapy and intensity modulation radiation therapy, but the concepts could also be applied to internal (brachytherapy) radiotherapy. The radiation beams could consist of photons or any charged or uncharged particles. The concept of optimizing source distributions can be applied to complex radiography (for example, flash x ray or proton) to improve the imaging capabilities of facilities proposed for science-based stockpile stewardship.

Adhesion Layer for Etching of Tracks in Nuclear Trackable Materials
Jeffrey D. Morse, Robert J. Contolini
U.S. Patent 6,261,961 B1
July 17, 2001
A method for forming nuclear tracks having a width on the order of 100 to 200 nanometers in nuclear trackable materials, such as polycarbonate (LEXAN), without causing delamination of the polycarbonate. The adhesion film may be composed of a metal such as chromium, nickel, gold, platinum, or titanium or composed of a dielectric having a stable surface, such as silicon dioxide, silicon nitride, or aluminum oxide. The adhesion film can either be deposited on top of the gate metal layer, or if the properties of the adhesion film are adequate, it can be used as the gate layer. Deposition of the adhesion film is achieved by standard techniques, such as sputtering or evaporation.

Reflective Optical Imaging Method and Circuit
David R. Shafer
U.S. Patent 6,262,826 B1
July 17, 2001
An optical system compatible with short-wavelength (extreme-ultraviolet) radiation comprising four reflective elements for projecting a mask image onto a substrate. The four optical elements are characterized in order from object to image as convex, concave, convex, and concave mirrors. The optical system is particularly suited for step-and-scan lithography methods. The invention increases the slit dimensions associated with ringfield scanning optics, improves wafer throughput, and allows higher semiconductor device density.

Awards

Laser and plasma physicist **Mordy Rosen** is one of two recipients of the prestigious **Edward Teller Medal** for 2001. The medal, awarded by the American Nuclear Society (ANS), recognizes pioneering research and leadership in inertial fusion sciences and applications.

Rosen, the former X Division leader and now its chief scientist, is recognized internationally for major contributions to the development of laboratory soft x-ray lasers. He has also contributed to the design and analysis of high-energy-density and inertial-confinement-fusion experiments. These complex experiments have been used to study electron and radiation transport and the properties of hot dense matter. This work—along with that of many others—provided an important foundation for the national science-based stockpile stewardship effort and contributed to Department of Energy approval of the National Ignition Facility being constructed at Livermore.

ANS is a not-for-profit international scientific and educational organization established in 1954 at the National Academy of Sciences in Washington, D.C., by individuals seeking to unify the professional activities within the diverse fields of nuclear science and technology.

Professor Stefano Atzeni of the University of Rome "La Sapienza" and the Italian National Institute for the Physics of Matter is the other winner of this year's Teller Medal. He and Rosen join a select group of 18 scientists from 9 countries who have been awarded the Teller Medal in previous years.

Quazi Hossain, an engineer in the New Technology Engineering Division, was recently honored with the title of **fellow** by the **American Society of Civil Engineers** (ASCE).

To qualify as an ASCE fellow, a civil engineer must be an active member of the society for at least 10 years, be a legally registered engineer, and demonstrate notable achievements in the advancement of the engineering profession. Hossain's achievements include distinguished service as chairman of the ASCE Working Committee on High Level Radioactive Waste Repository, for which he received an ASCE Certificate in 1991.

To advance to fellow, Hossain had to be nominated by a specialty committee of ASCE and three ASCE fellows. Promotion to fellow is one of the highest honors given by ASCE.

Hossain joined the Laboratory in 1992, working on projects related to natural hazard mitigation for nuclear facilities. He was the principal investigator for the Nuclear Regulatory Commission's Advanced Light-Water Reactor project and the principal author of the Department of Energy standard on seismic classification of structures, systems, and components. He was also a key contributor to DOE's standard on aircraft crashes on hazardous facilities, the Tornado Hazard Characterization project, and the project to develop seismic design criteria for the Yucca Mountain project. In 1998, Hossain began working for Livermore's Hazard Mitigation Center and was named a codirector in 2001.

Abstract

Tracking the Global Spread of Advanced Technologies

Lawrence Livermore's Center for Global Security Research (CGSR) has been sponsoring workshops involving some of the brightest minds in science and technology, government, and academia. The main focus of recent workshops was the rapid global spread of new technologies and their potential effect on national security. Last year, the CGSR brought together experts to discuss technology-driven threats to the U.S. and its allies in the 2015 to 2020 timeframe. Participants studied how the Internet, migration, multinational corporations, and global research collaborations are all helping to provide every nation as well as small extremist groups access to technical knowledge. The series of workshops, entitled "After Globalization: Future Security in a Technology-Rich World," resulted in a ranking of long-range threats to the U.S. An ongoing CGSR project titled "Whither Deterrence?" is examining the future of deterrence in response to the new threat scenarios. Other workshops and studies carry on the CGSR tradition of focusing on the interplay between policy and technology.

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Coming Next Month

Sharing the Power of Our Supercomputer Resource

Providing a "discovery environment" is the goal of a Livermore computing initiative that gives researchers from virtually every unclassified program access to high-performance computers.

Also in October

- ***Advances in ultrashort-pulse lasers are expanding this technology's applications and enhancing the quality of stockpile stewardship research.***

- ***Atmospheric scientists are using computational fluid dynamics modeling to better understand and predict chemical and biological dispersion in urban settings.***

- ***Livermore celebrates the 100th birthday of E. O. Lawrence, the Laboratory's founder.***

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