Sandia National Laboratories

A Department of Energy National Laboratory

SANDIA NATIONAL LABORATORIES

annual report 2003-2004

Helping our Nation Secure a Peaceful and Free World through Technology

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About Sandia

Sandia National Laboratories began in 1945 on Sandia Base in Albuquerque, New Mexico, as Z Division, part of what's now Los Alamos National Laboratory. Both labs were born out of America's atomic bomb development effort—the Manhattan project. Sandia came into being as an ordnance design, testing, and assembly facility, and was located on Sandia Base to be close to an airfield and work closely with the military. In 1949, President Harry Truman wrote a letter to the American Telephone and Telegraph Company president offering the company "an opportunity to render an exceptional service in the national interest" by managing Sandia. AT&T accepted, began managing the Labs on Nov. 1, 1949, and continued in the role for nearly 44 years. The Labs' original mission—providing engineering design for all non-nuclear components of the nation's nuclear weapons—continues today, but Sandia now also performs a wide variety of national security R&D work.

The Lockheed Martin Corp. has managed Sandia since Oct. 1, 1993, for the U.S. Department of Energy (DOE). Most of Sandia's work is sponsored by DOE's National Nuclear Security Administration, but we also work for other federal agencies, including the Department of Defense, Department of Homeland Security, and others. We work cooperatively with a number of government, U.S. industry and academic partners to accomplish our missions. Today Sandia employs about 8,000 people and has two primary facilities, a large laboratory and headquarters in Albuquerque and a smaller laboratory in Livermore, California.

Sandia Overview:
NATIONAL SECURITY *is our* BUSINESS

Sandia National Laboratories applies advanced science and engineering to help our nation and allies detect, repel, defeat, or mitigate national security threats. Our national security mission has grown from responding to the threat of the Cold War to countering a range of threats and adversaries—some nuclear, others involving chemical, biological or radiological weapons of mass destruction, and still others that are acts of terrorism.

We develop technologies to sustain and modernize our nuclear arsenal, prevent the spread of weapons of mass destruction, protect our national infrastructures, defend our nation against terrorism threats, provide new capabilities to our armed forces, and ensure the stability of our nation's energy and water supplies. Our science, technology and engineering program ensures that the nation will maintain national technological superiority and preparedness—keys to national defense, homeland security and our economic well-being.

We strive to become the laboratory that the U.S. turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe. After the horrors of Sept. 11, 2001, our nation did turn to us. We responded immediately, and continue to respond in a variety of ways. Technologies derived from our national security mission are being used across the nation and around the globe. We are playing a significant role in the new Department of Homeland Security and the military's Northern Command, whose mission is homeland defense and civil support.

We not only respond to national security needs as they develop, but try to "think in the future tense" about new types of threats that may develop soon or years down the road—and work to develop solutions before those threats become reality.

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A New Sense of Urgency

SCIENCE & ENGINEERING *for* NATIONAL SECURITY

As a national security laboratory, Sandia continues to focus on our primary mission—maintaining the nation's nuclear weapons stockpile. As threats to the nation's security have evolved, so has the mission of this laboratory, and much of our work these past few years has taken on a new sense of urgency.

Sandia's core vision is "Helping Our Nation Secure a Peaceful and Free World Through Technology," and our goal is to become the laboratory that the United States turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe.

In the past few years, Sandia has been tasked many times to deliver technologies quickly to achieve our vision and goal, and we have delivered proudly. Sandia's mission has expanded into combating terrorism, aiding homeland security, and supporting our military forces in Afghanistan, Iraq, and elsewhere. New technological advances must be quickly adapted to urgent applications in national security, and here Sandia's rapid prototyping and advanced manufacturing capabilities play a differentiating role.

In strategic planning exercises going back to the mid-1990s, we anticipated we would need to be prepared to deal with new kinds of threats:

- The proliferation of weapons of mass destruction,
- The vulnerability of our nation's infrastructure,

- Modern telecommunications technologies used by adversaries to attack our information and financial systems,
- Terrorism as a real threat to the U.S.,
- Military conflicts likely to be asymmetric and unconventional, and
- The nation's dependence on foreign energy sources.

We organized our business structures to address these issues and focused a substantial portion of our R&D funds to respond to the challenges. This report is organized into sections that basically reflect our business structures, which we call strategic management units (SMUs). Our technical mission SMUs include Nuclear Weapons; Nonproliferation and Assessments; Military Technologies and Applications; Homeland Security; and Energy, Information, and Critical Infrastructures. Our technical foundation SMU is Science, Technology, and Engineering.

Sandia also has an Advanced Concepts Group (ACG), which strives to anticipate and prepare for an uncertain future. The ACG is chartered to come up with solutions to future national security threats and problems that don't yet exist but are on the horizon. The goal is to harness the collective knowledge and creativity of a small, diverse group of particularly creative thinkers to help solve real future problems of importance to the security of our nation. It is sometimes called "Sandia's think tank."

Because we must often develop national security technologies quickly for fast-changing needs, Sandia's supporting services are organized into another agile strategic management unit. Called Integrated Enabling Services, it emphasizes speed of services for vital mission activities. Although not discussed in any detail in this report, it is vital to helping our technical organizations succeed.

Technology changes quickly, but among those things that do not change are the spirit and culture that is Sandia. We continue to create the kind of national security lab that is worthy of the freest nation in the world. There is no question that our work makes a difference. Sandia is doing its utmost to develop science and engineering solutions to national security problems. We do that with many of the best intellectual, scientific, and technical minds this nation has to offer.

We are now well into a five-year program to hire 2,500 new scientists, engineers, technologists and administrative staff—nearly a third of our current workforce must be replaced due to retirements. This highly educated, new group of Sandians will build upon the achievements of our proud, patriotic past in exciting and creative ways. What we continue to offer all employees—young and old—is the challenge to offer "exceptional service in the national interest." It is extremely heartening to see our newest employees accept this challenge eagerly.

We invite you to learn more on the following pages about the many ways Sandia's people are contributing to our national security and America's well-being. This report is not intended to cover all Sandia developments, but highlights selected work and activities that we believe are of particular interest to the public. For additional information about our capabilities and programs, and technical accomplishments, please see our website at **www.sandia.gov**.

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C. Paul Robinson
President and Laboratories Director

Joan Woodard
Executive Vice President and Deputy Director

Science, Technology and Engineering

EXPANDING FOUNDATIONS *for our* PROSPERITY *and* SECURITY

Not since the founding of the national defense laboratories at the dawn of the nuclear age and the following Cold War has America's security been as challenged as it is today. Fundamental capabilities in Science, Technology and Engineering (ST&E) are an ever more critical foundation of our nation's prosperity and security. We are in a new unstable global environment, and ST&E in support of our missions will be essential for Sandia to provide solutions to the nation's most pressing problems arising in this environment. The challenges are too complex to be solved by linear extensions of our existing knowledge and too urgent to await the serendipity of the usual innovation process. Meeting these challenges requires extensive strategic partnering with the university and industrial communities and, when appropriate, other government agencies and institutions.

Sandia's ST&E programs develop new understanding through the pursuit of basic and applied research, and integrate scientific results from all sources to provide the technology that supports Sandia's engineering and product realization needs. Our scientific and technological achievements are occurring at the boundaries between our research foundations and with critical support from our diverse engineering capabilities. Excellence in engineering no longer applies just to the design and qualification phases of a program but rather to the spectrum of activities from exploratory or technology development through full scale engineering development to deployment and eventual disposition.

To fulfill our new responsibilities within the nuclear weapons program and to meet the needs of our national security missions, we are creating a "Revolution in Engineering." We must innovate in our products and in our processes. We must be open to the push of new technologies, such as micro- and nanosystems technologies, and we must pull or guide them when necessary. Similarly, we must work to align the development of modern engineering tools, such as highly capable computational simulation, with our needs. Engineers must stay engaged with the science and technology community at Sandia, and extend engineering through new manufacturing processes that quickly deliver prototypes and deployable systems, not just designs.

For the future, our programs seek to leverage the science and technology emerging at the nano/info/bio/cogno interfaces to improve our security without infringing on our liberties, to defeat disease, and to enhance the overall well-being of mankind. Through partnering with universities, medical schools, and industrial corporations, we are adapting the evolved methods of bio systems to stimulate new approaches in micro, nano, info, and cogno technologies for Sandia's mission areas.

★ ★ ★

Pace VanDevender
Vice President
Science, Technology and Engineering

A STRONG SCIENCE, TECHNOLOGY AND ENGINEERING HERITAGE EXTENDS INTO THE FUTURE

In ending the Second World War, the Manhattan project produced nuclear explosives at least one million times more powerful than prior conventional explosives. Producing these weapons, which ended the scourge of global armed conflict, was not possible without partnerships of war-effort intensity and scope between universities, industrial and transportation companies, the Armed Forces, and a steadfast commitment from government. The science, technology and engineering programs at Sandia remain rooted in our primary mission as stewards of this nuclear deterrent to wars of global domination, and committed to producing advances of the same magnitude to end the newer scourge of terrorism.

Wars for domination of the world plagued civilization for nearly 4,000 years until 1945 when World War II ended. The war on terrorism should take far less time because huge advances in science, technology and engineering are providing effective tools and systems to defeat terrorists with hellish ambitions. Already in Afghanistan and Iraq, Sandia engineered and manufactured systems of extraordinary impact on the conduct of battle, such as synthetic aperture radars (SARs) carried on Predator drones. Only a few SARs, deployed worldwide, can quickly and radically change the balance of field operations.

Sandia continues its world-leading development of SARs, to make them more useful for both military and civilian applications. Recent development of interferometric terrain mapping capabilities enables large areas to be mapped at very high resolutions within a day, with the maps ready by the time the aircraft lands. In addition to providing new capabilities to military planners, these SARs could help map—at a precision thousands of times greater than today's maps—vast areas of the Earth that are virtually uncharted today, with a great benefit to civilian applications such as aviation, flood control and agriculture.

A second recent development of SARs, called coherent change detection, enables viewers to

Synthetic Aperture Radar (SAR) image of Washington, D.C. Sandia is the world's leader in the development of the special all-weather, day/night imaging technology.

detect sub-millimeter changes in a landscape over a period of time. These changes—for example, footprints across grass or leaves rustling in the breeze—could have startling military and nonproliferation applications. Once considered a mapping technology, Sandia has engineered SARs into event recorders.

Sandia's engineering excellence is now pushing SARs into new realms. Once installed in sizeable aircraft, now carried by drones, the micro-SARs of the future, using micro- and nanotechnologies, could be carried by very small aircraft or by micro-satellites.

SARs are only one system where Sandia brings its science, technology and engineering core competencies to bear. Our Grand Challenges inspire our scientists and engineers to make real concepts that are currently over the horizon of today's technologies. These challenges, in fields as diverse as atmospheric studies, energetic materials, nuclear and fusion energy, and reliability studies, attract new talent and partnerships across the nation.

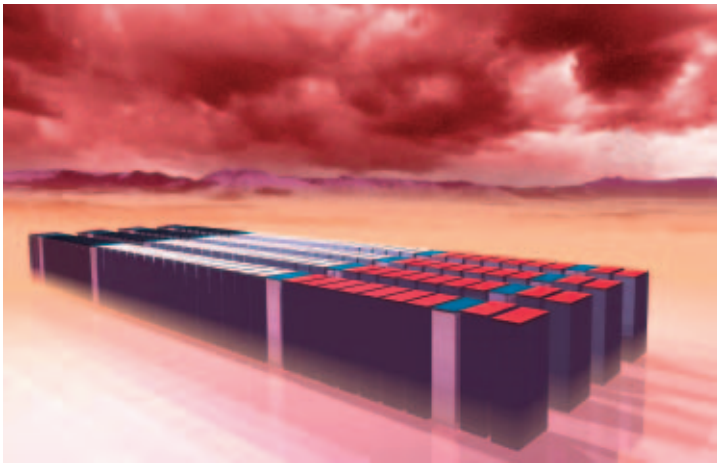
Technological advances in national security—the province of chemistry, physics and mechanical engineering for most of the 20th century—now occur at a far more complex and, obversely, fundamental level. For example, to build robust microsystems, Sandia scientists and engineers soon recognized that nano-scale phenomena came into play, and had to be understood and exploited. Nanotechnology, in turn, required an understanding of the ways biological creations assemble and disassemble.

As a multiprogram science-based engineering laboratory, Sandia is well positioned to translate these interfaces into applications that serve the national interest. More than ever, multidisciplinary and cross-disciplinary research will be critical to generating new insights and discoveries occurring at scientific boundaries.

COMPUTATIONAL CAPABILITIES MERGE MODELING/SIMULATION WITH TRADITIONAL SCIENCE METHODOLOGY

Our computational programs include the building of a 40-teraops (40 trillion operations/second) computer; the secure and ultra-fast networking needed for collaboration within Sandia and with other labs; the visualization systems to help comprehend vast data sets, and innovative and powerful software to fully use computational power to solve real-life problems.

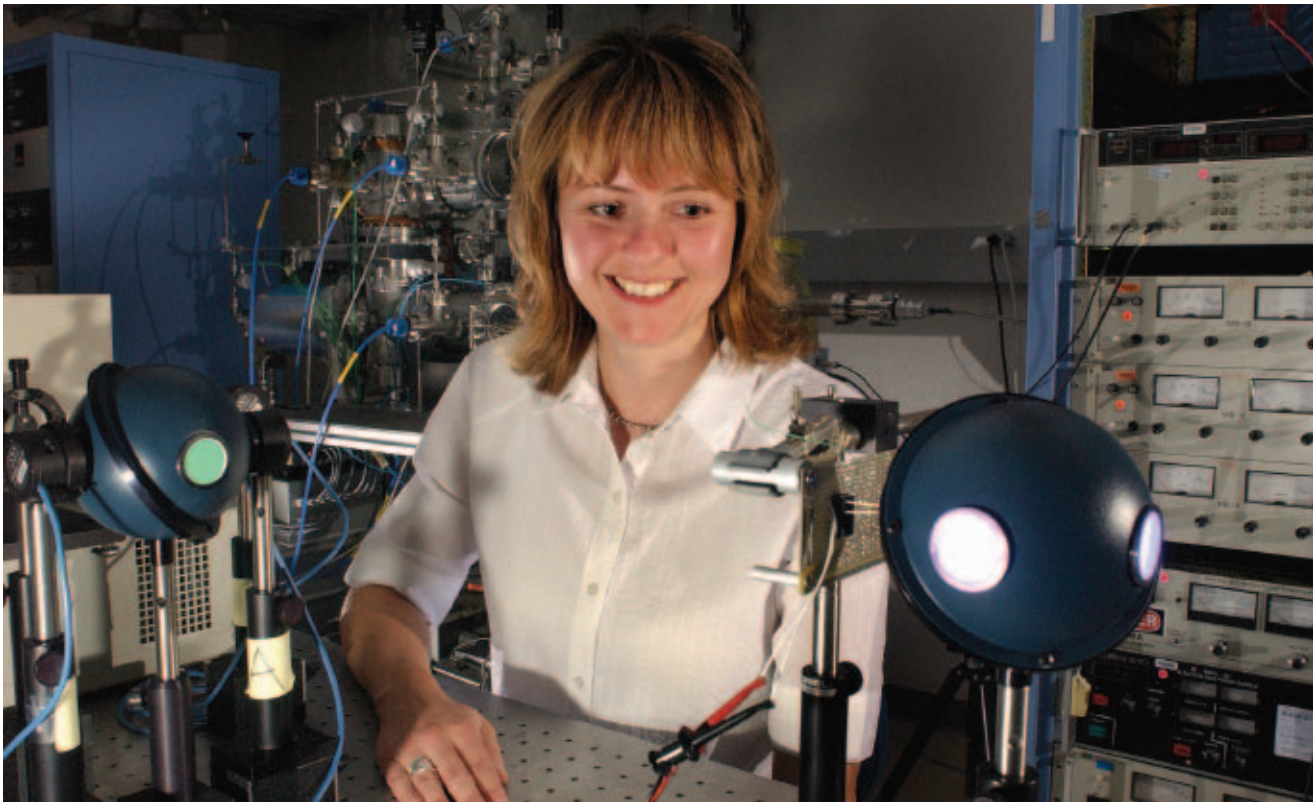
Sandia's contributions, recognized by three Gordon Bell awards—the highest computer science award—are integrating the traditional theory-and-experiment methodology with high-performance computational modeling/simulation to accelerate technical progress to solve previously intractable problems.



When completed in 2004, Sandia's new Red Storm supercomputer will be the world's fastest. It is being developed jointly by Sandia and Cray, Inc., and will have a peak speed of at least 40 trillion operations/second, or 40 teraops.

These programs also are creating and deploying the new architectures required to double computational capabilities every two years.

Supercomputing is revolutionizing the way we engineer and manufacture all kinds of products. Our supercomputing hardware has progressed since

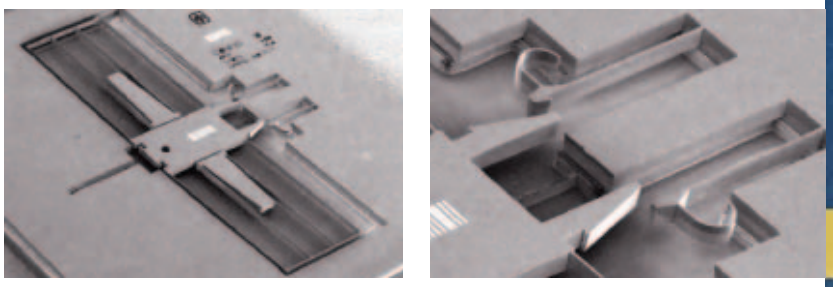


Lauren Rohwer leads a research team developing the first solid-state white-light-emitting device using quantum dots, which may represent a major application of nanotechnology.

1988 when our first NCUBE machine gave us the capability to do about 2.6 billion operations per second, or 2.6 gigaops. When the new Red Storm machine, developed with Cray, is completed in 2004, Sandia will again have the world's fastest computer, capable of doing 40 teraops. That's 15,000 times faster than the NCUBE. Sandia may even be able to push Red Storm up to 100 teraops.

We continued our work with the Extreme Ultraviolet Lithography (EUVL) consortium, working with industry and other national labs to produce next-generation technology for making computer chips with feature sizes 100 times smaller than current chips. We collaborated with IBM on nanotube transistors with unique characteristics not seen in silicon transistors. These tiny devices are about 2 nanometers, or about 10 atoms, across and promise to extend computer power well into the future.

Quantum computing, which uses phenomena at the quantum level of physics, could eventually replace today's digital computing. Sandia scientists are investigating and harnessing novel electronic effects in interacting nanostructures. Using state-of-the-art molecular beam epitaxy and electron beam writing, they fabricated systems of coupled quantum wells, coupled quantum wires, and coupled quantum dots. The innovative materials used in these systems are so pure that the electrons remember their phase over distances of up to 100 microns. Thus they behave more like waves than like particles, and can exhibit wave interference effects, anticrossings of energy levels, and novel



This microelectromechanical system safe and arm device, fabricated at Sandia's Compound Semiconductor Research Lab, has the potential to be used in future sophisticated weapon systems.

collective effects where the positions of individual electrons become correlated with their neighbors to form ordered, collective states.

ENGINEERING AND ADVANCED MANUFACTURING FOR A NEW GENERATION OF NATIONAL SECURITY TECHNOLOGIES

To meet our cradle-to-grave responsibilities in national security missions, Sandia has created engineering and advanced manufacturing programs that represent the nations' premier prototyping and small-lot, War Reserve quality manufacturing capabilities. Over the past decade, new and significant engineering tools have been developed, which Sandia exploits to fill the gap left when many production agencies were eliminated.

Sandia engineered new materials and advanced processes for neutron generators, a critical component that requires highly specialized equipment,

Randy Schmitt (left) and Mark Johnson with Sandia's Ares mobile biological weapons standoff detection system. Ares uses a ground-based portable ultraviolet laser-induced fluorescence lidar to help protect high-value facilities or high-visibility events.

processes, and testing that are infeasible outside the Nuclear Weapons Complex. The new-technology generators provide weapons systems engineers with the highest level of confidence in quality and performance.

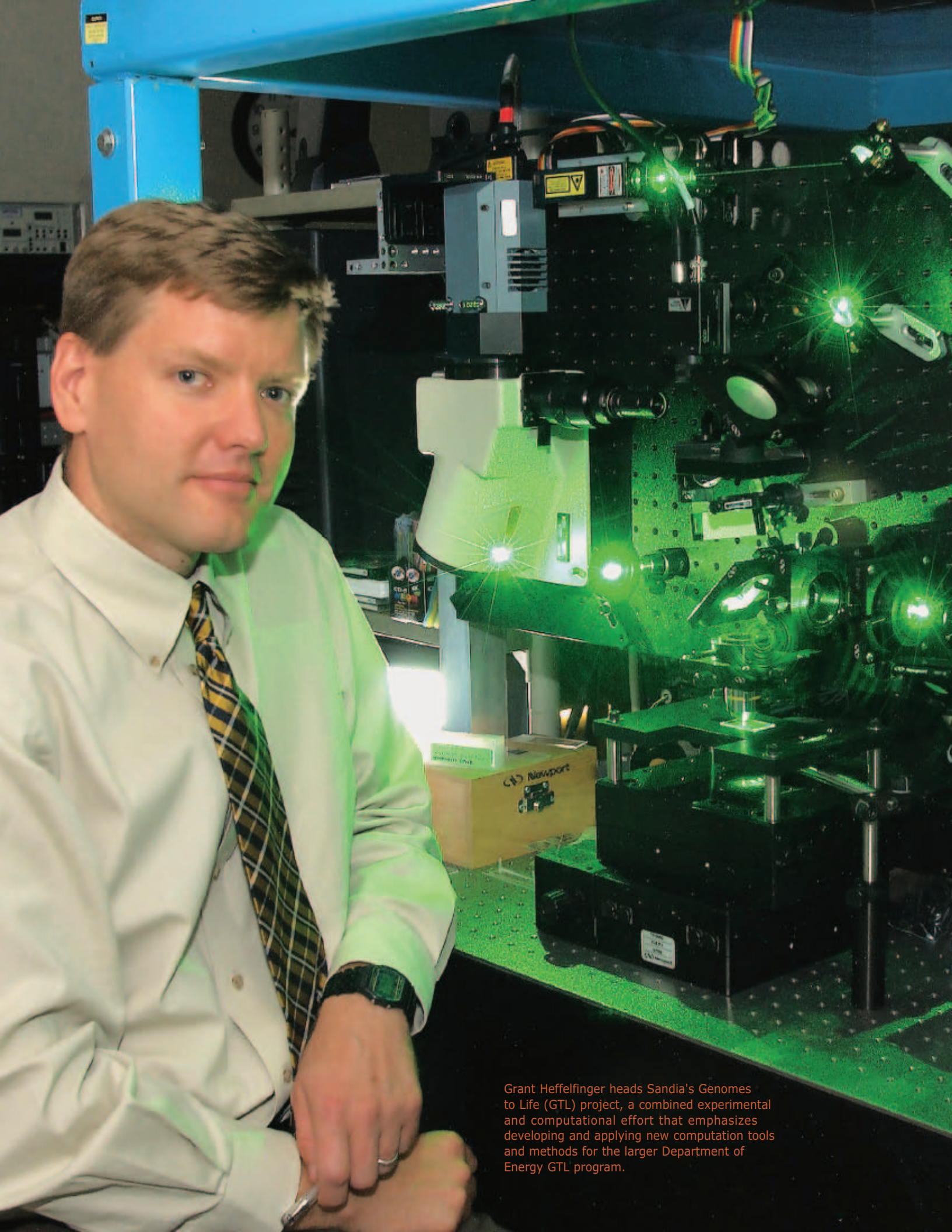
No less sophisticated are new components that extend the life of our stockpile systems. Since 1991, Sandia has delivered 60,000 advanced components for the non-nuclear functions of weapons systems. These engineered components have advanced the state-of-the-art in material sciences, applied physics, chemistry, electronics, and manufacturing sciences.

Sandia has tackled many difficult design and production problems for advanced systems for the Department of Defense (DoD). Today's demand for rapid deployment of advanced technologies led us to extend our efforts to the production of these technologies and their seamless transfer to commercial firms. This strategy extends Sandia's unique capabilities into traditional DoD and Homeland Security areas.

Sandia's fabrication capabilities are extensive. They include the ability to design and fabricate complicated flow channels with embedded electrodes in glass, to pattern monolithic porous polymers and post arrays within channels, and to employ deep reactive-ion etching, LIGA, embossing, casting, and micro-injection molding (LIGA is an acronym from the German words for lithography, electroplating, and molding). Surface properties can be tailored using plasma oxidation. Sandia is exploring the use of silicon-based complementary metal-oxide semiconductor (CMOS)-compatible microfluidic systems for high-voltage electrophoresis and other applications.

BIOTECHNOLOGY FOR UNDERSTANDING AND BETTERING QUALITY OF LIFE INCLUDES NATIONAL SECURITY

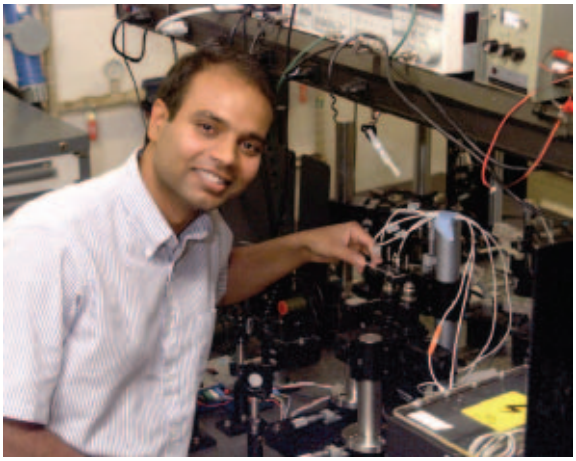
Our biotechnology programs are developing basic science and technology for understanding biological processes and their products, and harnessing these processes for national security applications. At our California site, researchers have made significant and unique contributions to the science of structural proteomics. Starting from a bare-wall 'bio'



Grant Heffelfinger heads Sandia's Genomes to Life (GTL) project, a combined experimental and computational effort that emphasizes developing and applying new computation tools and methods for the larger Department of Energy GTL program.

capability a little over two years ago, they are unraveling the complexities of membrane protein structures. This positions Sandia to play an important role in defense against biowarfare agents, particularly as protein-based receptors can be tuned to detect specific molecules, such as toxins.

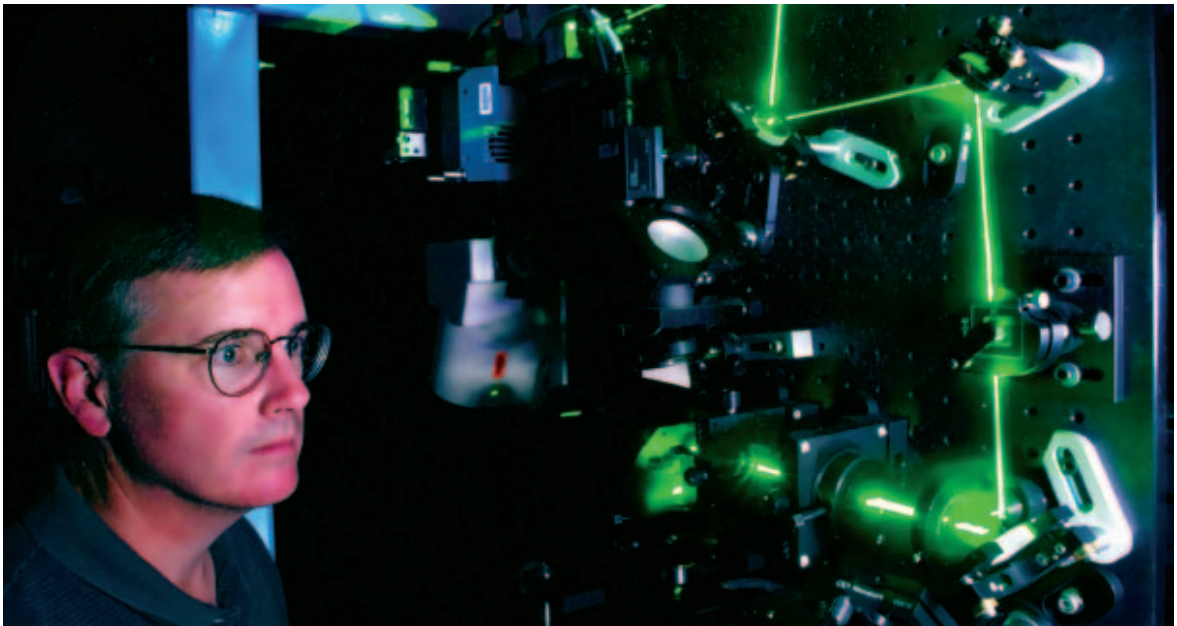
Sandia's Genomes to Life (GTL) project is developing computational methods and capabilities to advance understanding of complex biological systems and predict their behavior. The initial target for testing the new methods and tools is Synechococcus Sp., ocean bacteria that play a central role in climate change by fixing atmospheric carbon. This effort is aimed at developing and applying computational capabilities for Synechoccus for application to the larger DOE life-science community. The Sandia-led GTL project includes participants from four DOE laboratories, three universities, and four institutes with diverse backgrounds ranging from biology to physics to mathematics. The capabilities to be developed are equally diverse, ranging from new experimental methods to extensions to massively parallel operating systems.



Sandia's Anup Singh detects protein separations. He and several research collaborators discovered a lab technique they call electrokinetic trapping. Proteins can be trapped and concentrated at specific locations by turning on voltage, and released by turning it off.

Jim Voigt (left) and Jun Liu are part of a team studying physical and chemical principles behind the formation of natural materials, and is developing synthetic routes to achieve similar structural control for the production of complex nanomaterials.

Work is under way to identify and learn how to exploit key strategies used by living systems to develop materials whose assembly and disassembly can be programmed or self directed. This may lead to new nanomaterials that can be programmed for assembly, reconfiguration, healing and disassembly.



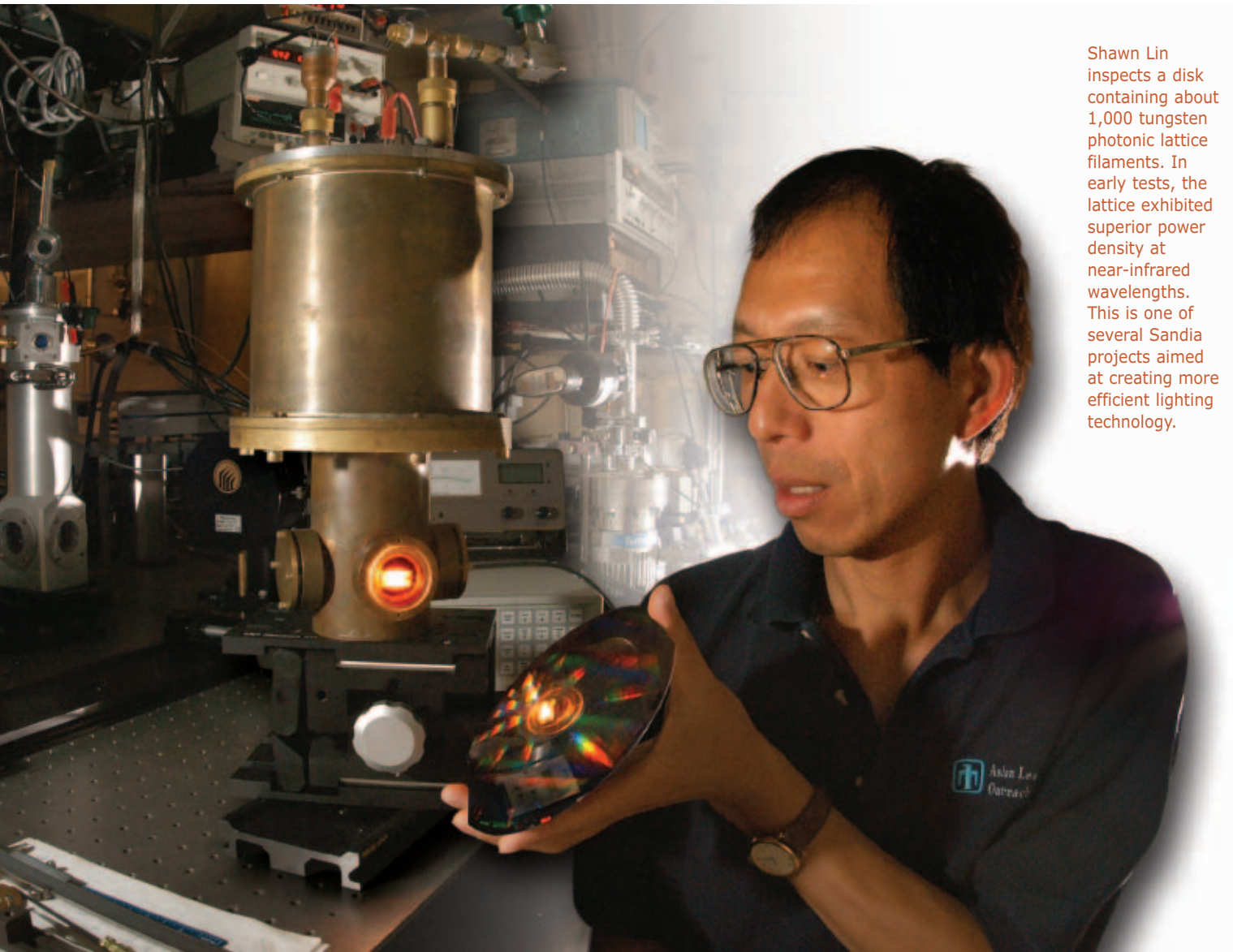
Researcher Mike Sinclair designed, and with help of co-workers, built the Hyperspectral Microarray Scanner for Microarray Analysis to scan glass slides containing DNA. The scanner provides huge amounts of data that is analyzed using Sandia-developed algorithms and software.

Just as the ability to direct and bound processing on the micro-scale via semiconductor lithography has enabled scores of electronic advancements, the ability to pattern and direct biochemically relevant molecules will open new horizons in engineering at the molecular scale.

If we hope to achieve comparable levels of efficiency or specificity in engineered, chemical microsystems, we will require similar skills associated with the directed placement of molecules within our man-made engineering designs. The successful demonstration of multi-level patterning of DNA, phospholipids, proteins, and cells has been the first step toward achieving this molecular scale organization. This work supports sensor designs ultimately based upon single molecular responses. We have successfully developed a hyperspectral scanner for microarray analysis that has greater sensitivity than any commercial microarray scanner. The new instrument measures the entire emission spectra of the tagged DNA fragments for each pixel location on the microarray. This new capability has already been used to identify issues associated with standard microarray analysis and will be used to significantly enhance the understanding of gene expression.

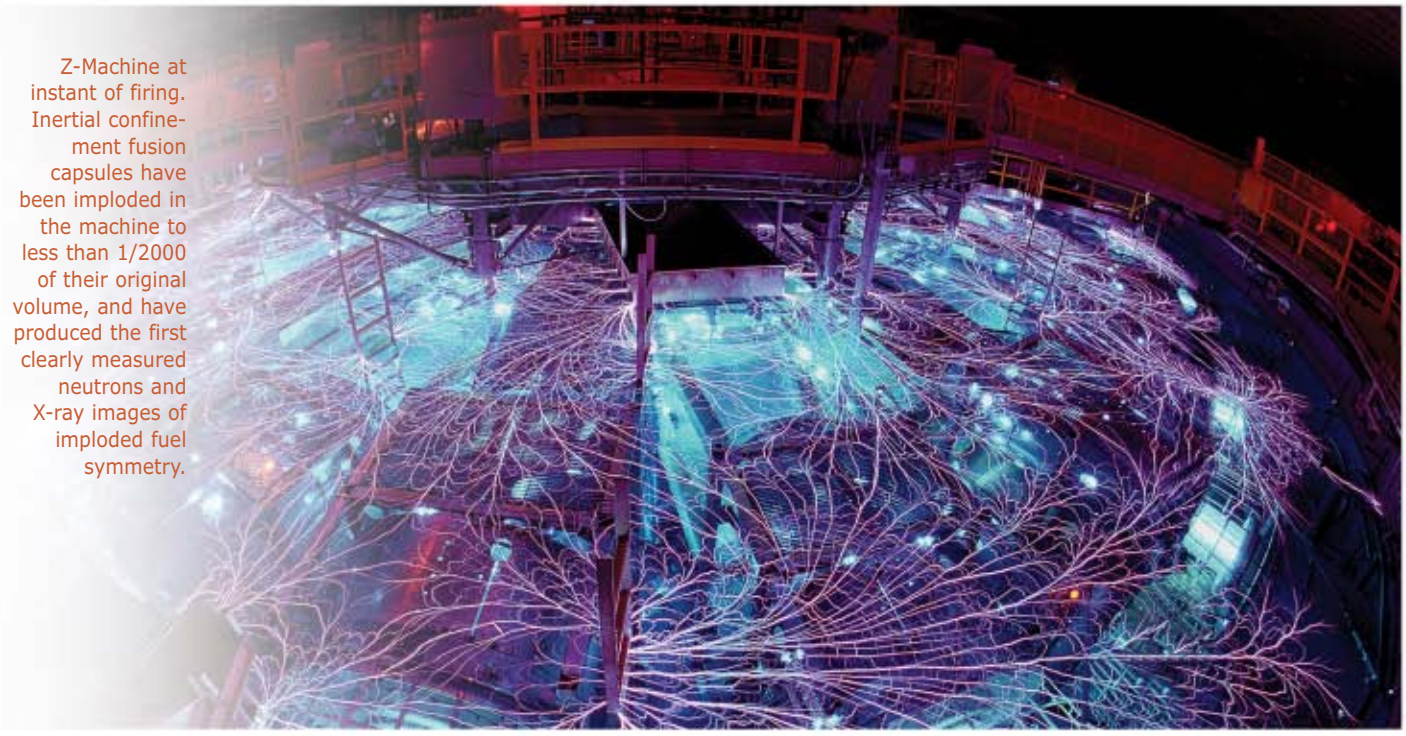
MATERIALS SCIENCE AND MICROTECHNOLOGIES

As weapons systems advance and material performance requirements are pushed to extremes, we must



Shawn Lin inspects a disk containing about 1,000 tungsten photonic lattice filaments. In early tests, the lattice exhibited superior power density at near-infrared wavelengths. This is one of several Sandia projects aimed at creating more efficient lighting technology.

develop new materials to match these environmental extremes. In many cases, components can survive only if the environmental loads can be shared with a secondary, synergistic structure. We developed new potting foams with exceptional toughness that absorb energy imparted by extreme environments and distribute impact forces broadly, preventing catastrophic failures in new weapon applications.



Z-Machine at instant of firing. Inertial confinement fusion capsules have been imploded in the machine to less than 1/2000 of their original volume, and have produced the first clearly measured neutrons and X-ray images of imploded fuel symmetry.

We have developed materials and techniques for fabricating insulating microvalves that can control high-pressure fluid flow and high voltages in microchannels. These microvalves function by opening and closing the microchannels in response to electrical or pressure inputs. By generating a hybrid system composed of glass microchannels, porous polymeric elements, and high-dielectric-strength interstitial liquid, currents induced by high-voltage inputs may also be controlled. Together, these capabilities allow for modular integration of multiple electrokinetic and chromatographic analyses on a single glass chip, and advance our sensor technologies.

A ceramic microscaffolding—a layered mesh stronger than bone, yet porous—could substitute for a bone implant until healthy, newly grown bone and blood vessels weave their way through it. The quality of fit—improved by computer imaging and modeling—could produce a prosthetic device that would fit seamlessly where needed. Built mainly of hydroxyapatite, a material already approved by the FDA for bodily implants, approval of the new prosthesis could be swift.

In past research, Sandia's photonic lattice showed the ability to bend light with no loss of efficiency. Now a microscopic tungsten lattice—a filament fabricated with an internal crystalline pattern— has the potential to transmute infrared energy into the frequencies of visible light. This would raise the efficiency of an incandescent electric bulb from five percent to greater than 60 percent and greatly reduce the need for excess electrical generating capacity and reduce the costs of electrical lighting. The advance also opens the possibility of increased efficiencies in thermal photovoltaic applications

(TPV). Using a tungsten lattice as an emitter, model calculations show that the TPV conversion efficiency reached 51 percent compared with 12.6 percent with a conventional emitter.

Nanotechnologies at Sandia will be developed at a new facility, the Center for Integrated Nano Technologies, or CINT, in a joint program with Los Alamos National Laboratory. CINT will have four areas of expertise: photonics lattices and quantum clusters; complex, self-assembling nanostructures; the mechanics of behavior at the nanoscale; and importation of biological principals and functions into nano- and microsystems. Nanotechnologies enable our critical work in microsystems. Nanomechanics and nanotribology (the study of friction), for example, are fundamental for working silicon micromachines and microdevices produced by the LIGA process.

Z-MACHINE PRODUCES FIRST FUSION NEUTRONS

We continue to leverage Sandia's and other leading institutions' expertise and successes in pulsed power, high energy density physics, and material dynamics for the nation's pressing issues in weapon science, thermonuclear fusion energy, and national security applications of high-power and high-power-density beams.

Sandia's Z pulsed-power generator, the most powerful X-ray generator on Earth, has become a nationally recognized capability for dynamic materials research. Progress continued with the achievement of a 28 km/sec. flyer plate velocity, publication of new deuterium equation of state data, and several material dynamics experiments relevant to nuclear weapon stockpile stewardship.

Inertial confinement fusion (ICF) capsule implosions in the Z machine have produced the first clearly

SENSORS— OUR TOOLS

Nowhere are the micro/nano/info/bio/cogno interfaces of science more apparent than in the area of sensors, which are our tools to create an integrated capability to sense, visualize, simulate/understand and manage the complex interactions among earth, atmospheric and man-made systems. Sandia's development of surface acoustic wave (SAW) sensors holds nearly the same world recognition as our synthetic aperture radars (SARs).

SAW technology enables wireless receivers the size of a grain of rice and able to operate on no power except that carried by an incoming signal. SAWs will enable many new applications that depend upon miniaturized unattended or embedded sensors and instruments. Much like an old crystal radio set, these receivers convert specific radio waves to information which can be used to "wake up" larger systems. Sandia fabricated a SAW chip that stores the energy of a specific incoming signal, and then produces an output signal. This technology reduces the space and power needs of systems such as locator/inventory tags and relay communications in, for example, swarms of "cooperating" miniature robots.

But this is only the beginning.

continued on the next page.

Darren Branch experiments with the lipid bilayer biosensor that shows promise of rapidly detecting a variety of biological agents.

We are developing a commercially viable prototype of an acoustic biosensor for detecting low levels of bacteria in near real-time. The biosensor will include a handheld electronic device and a disposable fluidic cartridge that houses the sensor transducer. The development of the biosensor is part of a cooperative research and development agreement (CRADA) with Minnesota Mining and Manufacturing Company (3M). This CRADA combines Sandia's expertise in acoustic wave sensing, microsensor integration, and microelectronics design with 3M's competencies in separations, materials, microfluidics, and state-of-the-art manufacturing to prove the feasibility of developing rapid microbial detection products for applications in biological warfare detection and in the healthcare industry.

Combining genetics and molecular biology techniques, Sandia is generating cell lines that will uniquely fluoresce in response to specific toxins. Each cell line will respond to a variety of toxins by turning different colors. Living cells, like the canaries once used to detect toxic gases in coal mines, respond physiologically to unknown toxins. We are creating sensor arrays that utilize living cells as active sensing elements. In addition, these cells will be patterned/printed onto a variety of substrates including MEMS fluidic architectures or micro-robots for remote sensing. We have demonstrated cells capable of detecting cholera. We have also developed cells that express blue and yellow in response to environmental stimuli. We are currently developing an efficient means of printing the genetically tailored cells in nanomaterials and writing patterned cell arrays on a variety of substrates as small, autonomous, mobile sensors.

Combining physics and semiconductor technologies, many chemical and biological agents fluoresce when illuminated with ultraviolet (UV) light, including anthrax spores. Sandia is developing semiconductor light-emitting diodes (LEDs) in the UV region of the spectrum. Only recently has it become possible to make LEDs in the UV, due to the rapid development of gallium nitride-based materials. Sandia is performing this work partly under the sponsorship of a Defense Advanced Research Projects Agency (DARPA) program to develop small handheld anthrax detectors.

Sandia and Lockheed Martin jointly developed a small chemical sensor, called the SnifferStar, that can be deployed on

Christine Mitchell looks through a substrate that was made for the new cantilever epitaxy growth process, which gives potential for longer-lived and better-performing light-emitting diodes (LEDs).

Unmanned Aerial Vehicles (UAVs). The complete SnifferStar weighs just over 15 grams. Tests have shown that the sensor can detect low levels of blister agents and nerve agents. Interferents such as benzene, toluene, and xylene at much higher levels have only a minor impact on the output of the sensor. Processing time from sample collection to final report is 20 seconds. A programmable integrated micro-controller on the SnifferStar controls the operation of the sensor, collects the data, and relays information to a main data processor or communication link on the UAV.

measured neutrons and X-ray images of imploded fuel symmetry. We confirmed that deuterium fuel reached temperatures found at the center of the sun (about 11 million degrees C.). Capsules have been imploded to less than 1/2000 of their original volume, implying a radiation-drive symmetry that scales to within approximately a factor of two of high-yield fusion requirements.

Sandia's Z-Beamlet, the third largest laser in the world, confirmed that the Z machine spherically compressed a simulated fusion pellet. Uniform 3-D compression is an essential step in creating controlled nuclear fusion. It means that almost none of the X-ray energy delivered to the pellet is squirting uselessly away. Instead, the energy is compressing the pellet and forcing its atoms closer to fusing.

Technologist Benjamin Thurston examines the debris shield that protects the giant Z-Beamlet laser's focusing lens from flying debris when the Z accelerator fires.

Science, Technology and Engineering

TECHNOLOGY PARTNERSHIPS: TEAMING to ENSURE MISSION SUCCESS

Sandia works in partnership with industry and universities to enhance the security, prosperity, and well-being of the nation. Industry and university partnerships are key to our mission of providing cost-effective scientific and engineering solutions to meet national needs in nuclear weapons and related defense systems, homeland security, energy security, and environmental integrity—and to address emerging national challenges for both government and industry.

Sandia leverages partnerships to stimulate and augment its R&D endeavors, positively impact the domestic economy, and ensure the availability of mission-critical components.

Sandia's partnership and commercialization program is perhaps the most active and successful in the Department of Energy (DOE) laboratory complex. Since its inception in the early '90s, Sandia has executed more than 525 Cooperative Research and Development Agreements (CRADAs), 800 Non-Federal Entity agreements, 650 commercial licenses to Sandia-developed intellectual property, and more than 2,150 small business assistances. In addition, Sandia has provided technical assistance to more than 700 small businesses in New Mexico through an innovative program sponsored through tax credits by the State of New Mexico.

CRADAS AND OTHER TYPES OF PARTNERING

Umbrella CRADAs have been developed as the preferred contractual instrument for implementing strategic and enduring relationships. At least 15 such agreements have been executed with industrial partners including Goodyear Tire and Rubber Company, Boeing, Procter & Gamble, Bristol-Meyers Squibb, General Electric, the Cold Spray Consortium, Raytheon, Rockwell Collins, and Eclipse Aviation.

Sandia's relationship with Lockheed Martin, the Shared Vision program, serves as a model for strategic partnerships. Doubling in size the past year, this highly successful collaboration is applying technologies and systems developed by both organizations to the challenging defense and security threats of our changing world. Technologies with applications for both government and industry have included microelectronics and photonics, sensors, situation and decision support modeling, cognition, nanotechnology, biotechnology, anti-tamper devices, and logistics support.

Sandia's participation in the Extreme Ultraviolet Lithography (EUVL) consortium with six industry partners and three national laboratories and the Cold Spray consortium with ten industry partners are models for developing new technologies that will have great impact on the nation's largest industries. (See more information in next section, Award-winning partnerships.) Commercialization of this breakthrough technology will allow advances in microelectronics to continue into the next decade.

The Cold Spray consortium (Pratt & Whitney, Ktech, Johnson Manufacturing, Ford Motor Co.,

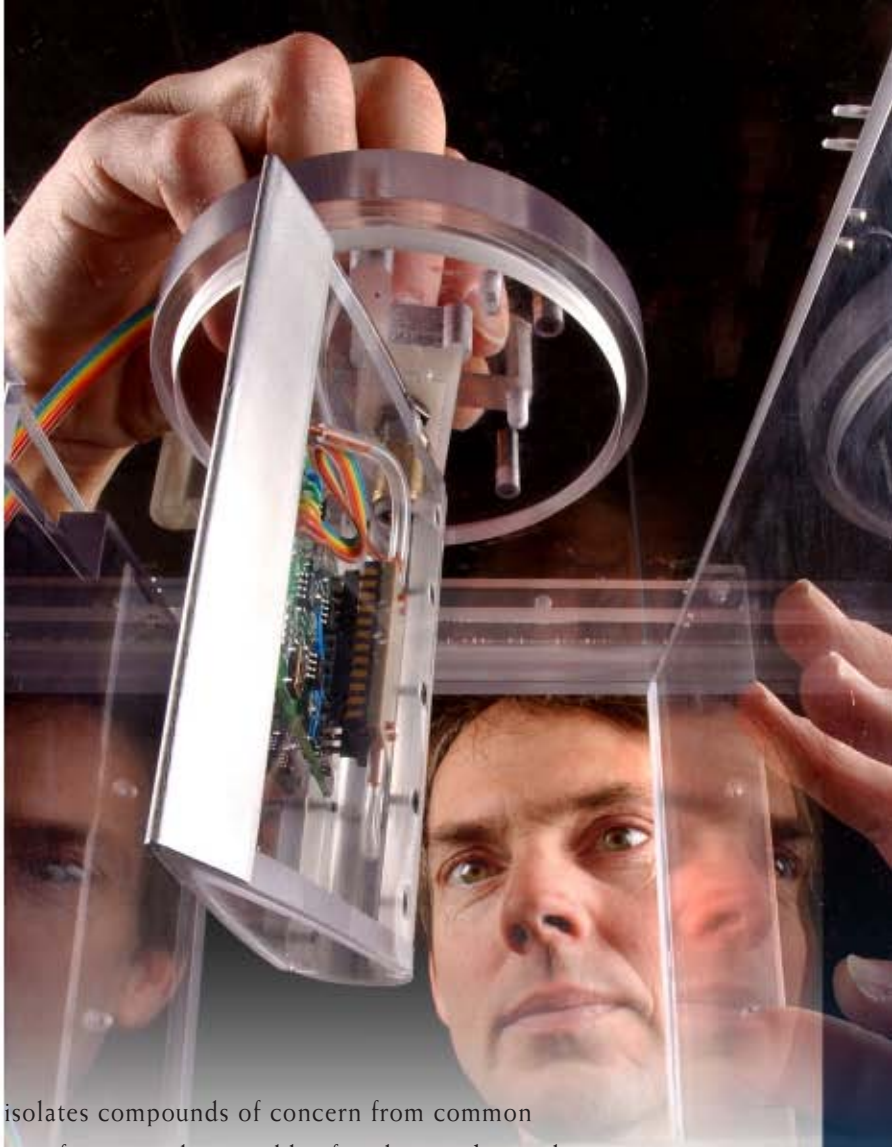
ALCOA, ASB Industries, DaimlerChrysler, Siemens Westinghouse Power Corp., Jacobs Chuck Manufacturing Co., and Praxair) has advanced the science and art of applying coatings and joining materials through high-velocity particle impact. This emerging manufacturing technique is broadly applicable and carries many advantages over traditional high-temperature metal forming processes.

AWARD-WINNING PARTNERSHIPS

The R&D 100 Awards, which annually honor great advances in technology, are just one measure of Sandia's success in developing technologies that impact the nation's security and prosperity. Sandia partners with universities, other laboratories, and small and large industrial firms on the following award-winning technologies:

Developed under a Lockheed Martin Shared Vision program, the SnifferStar™ mounts on a drone aircraft for remote surveillance of battlefield situations where plumes containing chemical or biological agents are suspected. The entire module weighs less than a golf ball, operates on 0.5 watts, and uses the wind generated by the motion of the craft to collect samples for analysis. SnifferStar™ technology isolates compounds of concern from common interferents and is capable of analyzing chemical blister and nerve agents in 20 seconds. The device also has potential for use in public buildings and military bases.

Mark Smith (right) explains Sandia's Cold Spray coating system to three industry representatives. An industry consortium has advanced this broadly applicable technology.



Doug Adkins led the joint Sandia/Lockheed Martin project that developed the R&D 100 Award-winning SnifferStar, which mounts on drone aircraft to check for the presence of chemical weapons on a battlefield.

Acoustic telemetry technology, developed at Sandia in cooperation with Extreme Engineering Ltd. of Calgary, Alberta, and with support from DOE, represents the fulfillment of an oil-industry quest that goes back to the 1940s. As more accessible reserves have been depleted, deeper and more complex extraction techniques have become necessary, making better communication between the driller and the drill bit more critical. Existing communication methods, based on mud-pulse techniques, were revolutionary when introduced in the early 1980s. But mud-pulse is slow—much, much slower than even first-generation telephone modems. Acoustic telemetry technology uses the well-drilling tubing as the data transmission medium and sound waves as

Sandia researchers work with the Extreme Ultraviolet Lithography (EUVL) light source with a new laser. The system, expected to lead to dramatic improvements in the speed and memory of computer systems, received a 2003 R&D 100 Award.

the data carrier, creating a 10-fold improvement in data rates and thereby improving drilling control and accuracy.

A large group of collaborators from Sandia, Lawrence Livermore, and Lawrence Berkeley national laboratories were honored for developing the Extreme Ultraviolet Lithography (EUVL) Full-Field Step-Scan System, a technological advance that will lead to dramatic improvements in the speed and memory of computer systems. (See also previous section). Researchers created the only system that can pattern full chip-size areas on silicon wafers with features as small as 50 nanometers. It is the embodiment of a set of groundbreaking technologies that were considered by many to be impossible as recently as a few years ago. In addition to the national laboratory team, the award was given jointly to Northrop Grumman Space Technology/Cutting Edge Optronics. The work was done in partnership with an industrial consortium comprising Intel, Motorola, AMD, Infineon, IBM, and Micron. Intel ordered the first production-level instrument based on this technology last year.

The Low Emissions Atmospheric Metering Separator (LEAMS) is a family of atmospheric geothermal separators used in developing geothermal power. LEAMS safely contains and cleans the steam vented into the atmosphere of polluting solids, liquids, and noxious gasses. LEAMS can be used in drilling, well testing, and geothermal power plant start-up. In partnership with Sandia, LEAMS technology was developed by Two-Phase Engineering and Research, Inc., Santa Rosa, Calif., and fabricated by Drill Cool Systems, Inc., Bakersfield, Calif.

The Adaptive Optics Phoropter system uses MEMS-based deformable mirror technology in a compact, transportable system that expands upon traditional devices used for optometry. In addition to determining corrections needed for near-sightedness, far-sightedness and astigmatism, it also determines correction needed for high-

order aberrations that can interfere with night vision and can provide a preview of correction to a patient. Technologies from astronomy and micromachining are combined to advance the study and treatment of retinal diseases. Applications for the tool include generation of improved prescriptions for custom contact lenses or laser eye surgery, as well as high-resolution retinal imaging. The partnership, led by Lawrence Livermore National Laboratory, includes Sandia, the University of Rochester, Wavefront Sciences, Boston Micromachines Corp., and Bausch & Lomb.

Lightning strikes, equipment failures, or other anomalies in electric powered transmission systems can cause brown-outs or even network failures. But a fast-response semiconductor device developed under Sandia's direction allows a utility to rapidly convert energy stored in a DC device into AC power and minimize the effects of interruptions on electrical devices. Under the auspices of the DOE Energy Storage Systems Program, Sandia led researchers at Virginia Tech in developing the advanced semiconductor unit, called an ETO (emitter turn-off thyristor). The ETO is rated at 4000A and 4500V and can switch power at 1-3 kHz—far exceeding other devices. The component could become a critical part of inverters, motor controllers, and many other power electronics systems that require medium voltage and high-current switches. In addition to inventors at Virginia Tech, the ETO was developed with Solitronics (a Blacksburg small business marketing the ETO) and the American Competitiveness Institute in Philadelphia.

Although the project involved no partners, Sandia also received a 2003 R&D 100 Award for creating microvalves that allow fluids to be shuttled as easily in microfluidic chips as they are on a traditional laboratory benchtop. These valves enable microscale systems to combine high-voltage and high-pressure analytical or synthetic techniques. Previous micro-scale systems could not effectively control both electrokinetic and high-pressure hydraulic flow.

MEETING THE NATION'S BIGGEST CHALLENGES

Sandia technologies have helped improve the nation's security and the capabilities of a vast range of partners, in fields as diverse as infrastructure risk assessment, microelectronics, and increased energy production. Recent examples include:

- Sandia's Risk Assessment Methodology (RAM™) has been extended to provide protection to dams, transmission lines, and water utilities. Each of these methodologies has been licensed so that this important capability is available to protect the nation's infrastructure. More than 210 RAM licenses have been executed.

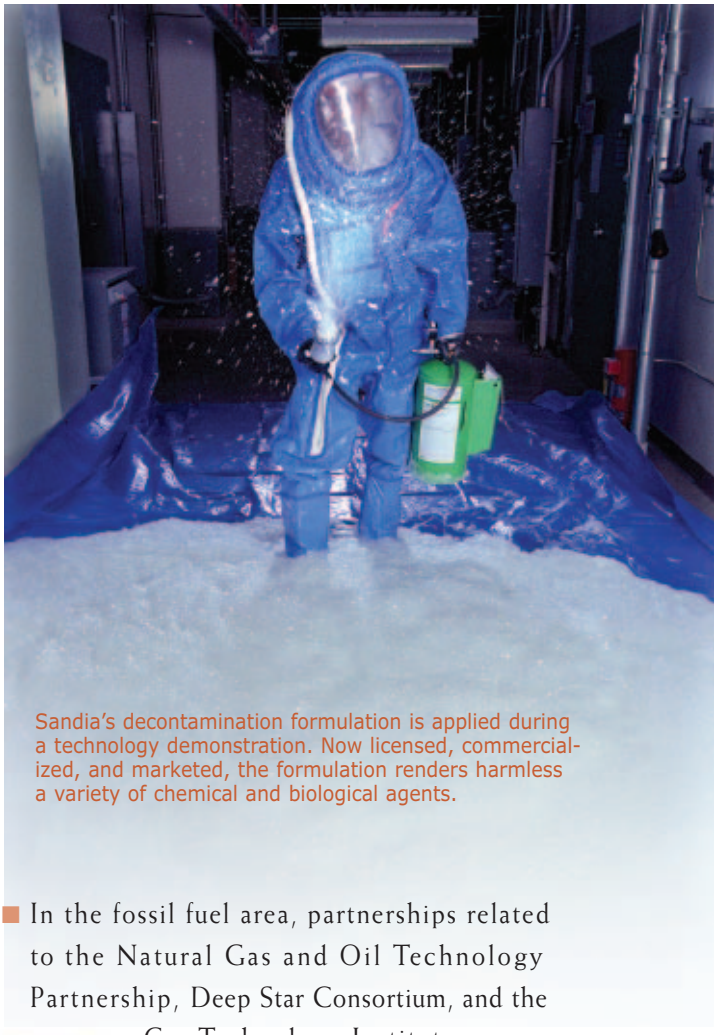
- Furukawa Electric Co. and Honeywell Inc., leaders in communications, electronics, and energy technologies, were added to the list of licensees holding nonexclusive rights to one of Sandia's vertical cavity surface emitting laser (VCSEL) patents. These licensees and the five predecessors (Emcore, eCielo, Opticomp, Xerox, and Agilent) solidify the industry's acceptance of Sandia's patent portfolio as part of VCSEL technology's foundation.

- Sandia's decontamination formulation that renders chemical and biological warfare agents harmless has been selected for use by the U.S. Army Central Command (CENTCOM). CENTCOM placed an order with EnviroFoam™ Technologies for several thousand gallons of the company's EasyDECON™

solution, some of which was stockpiled in case U.S. troops encountered chemical or biological agents in Iraq.

- The Sandia-developed Instant Shooter ID Kit (ISID-1) continues to receive praise—and purchase orders—from law enforcement officials and U.S. military services. On January 30, 2003, the North Charleston, S.C., police department used ISID-1, produced by Law Enforcement Technologies, Inc. (LET) of Colorado Springs under license, to identify and arrest four suspected shooters. Based on the events of that evening, the U.S. Attorney's office decided to make a volume purchase of ISID-1 kits for the North Charleston PD. News reports in the summer of 2003 also indicated that the kits were being used by the military services to help maintain order in Iraq, Afghanistan, and elsewhere.

- Sandia signed a commercial license agreement with Law Enforcement Technologies for the Sandia-developed fuel-air ("flash-bang") diversionary device. The device, which greatly reduces the risk of inadvertent injury to users and hostages, while impairing adversaries, will be available to law enforcement and the military.



Sandia's decontamination formulation is applied during a technology demonstration. Now licensed, commercialized, and marketed, the formulation renders harmless a variety of chemical and biological agents.

- In the fossil fuel area, partnerships related to the Natural Gas and Oil Technology Partnership, Deep Star Consortium, and the Gas Technology Institute assure research is applied to US energy production.

- Sandia's work on geological storage of spent nuclear fuels is the basis for continuing partnerships with institutions in Japan, Korea, and Taiwan, maintaining in-house technical excellence while helping to

Explosives expert Pam Walker and Maj. Mike Tachias of Sandia's Protective Force and an Army Reserve member demonstrate use of a new military version of a Sandia-developed instant shooter ID kit that has been commercialized by Sandia partner Law Enforcement Technologies, Inc. Different versions of the kits are being used by law-enforcement agencies and by the U.S. military services.

assure the appropriate storage and protection of nuclear wastes in these countries in the future.

- Sandia maintains more than 25 User Facilities that allow industry access to unique facilities and capabilities in key areas such as combustion research.

tionally contracted for university research to expand its science and technology base to assure the performance of its nuclear weapons, but many other partnering opportunities exist now in other Sandia mission areas.

Both Sandia and universities share a need to

Sandia Security Police Officers demonstrate a fuel-air "flash-bang" device that has been licensed for commercial development and sales to law-enforcement agencies and the military.

A COMMITMENT TO UNIVERSITY PROGRAMS

Sandia's highest goal is to become the laboratory that the U.S. turns to first for technology solutions to the most challenging problems that threaten peace and freedom for the nation and the globe. University partnerships are a critical element in achieving this goal. Sandia has traditionally contracted for university research to expand its science and technology base to assure the performance of its nuclear weapons, but many other partnering opportunities exist now in other Sandia mission areas.

Both Sandia and universities share a need to accelerate the creation of world-class research, produce scientists and engineers, and grow competencies and new businesses. Today, Sandia partners with key universities to achieve three major objectives: conduct world-class science, hire world-class scientists and engineers, and develop strategic collaborations in focused research areas. In FY02, Sandia invested about

$23 million in joint research projects with universities. We work with about 120 universities annually and have about 500 active contracts with them. Sandia also devotes about $15 million a year for graduate student support and university and science outreach.

The Sandia Campus Executive Program provides a framework for Sandia to focus our research goals and helps us create the 21st century workforce needed to perform the technical jobs crucial to fulfilling our national security mission. Sandia executives, acting in the role of ambassadors, are paired with top university officials (usually deans of engineering) at schools that have synergistic research interests and capabilities with Sandia. These Sandia executives work with the universities to implement programs established for the express purpose of furthering the goals of both Sandia and the universities. The campus executives and their teams visit their assigned universities once or twice each year, serve on university advisory boards, and attend special events. They actively support placing students in the numerous Sandia programs.

Sandia's Joe Cesarano shows how his team's patented Robocasted mesh implant fits inside the jawbone of a simulated skull. Sandia is working with the University of Illinois to determine whether the stronger-than-bone implant technique can gain FDA approval for live testing.

Sandia partners with universities on numerous research projects, some also involving other government or industrial partners. This collaboration often produces important results and leads to significant breakthroughs.

- One example is a recent collaboration between Harvard University and Sandia. Harvard developed a technique to develop extraordinarily tiny holes, of about 2 nanometers diameter, in silicon nitride. Concurrently, Sandia was developing a stable protein channel of the same diameter. Working together, these two technologies "may one day make it possible to sequence your genes during a visit to a doctor's office," remarked Dr. William Cromie of the University of Chicago, writing in the *Harvard University Gazette*.
- Another example involves how Sandia continues exploiting the synthesis of microtechnology with information technology through modeling, simulation, process development, and production of micro-devices and the deployment of networks of microtechnologies. The Variable Emissivity Shutters project is a joint project with Johns Hopkins University Applied Physics Laboratory and NASA/Goddard Space Flight Center. This project developed a microelectromechanical systems (MEMS) thermal control device that will be installed in two NASA micro satellites scheduled for launch in late 2004. Each satellite will contain 90 sq. cm. of these devices, which will be evaluated for their thermal-control capability. The louvers are micromachined devices, which are similar in function and design to conventional mechanical louvers where a mechanical vane or window is opened and closed to vary the radiant heat

President George W. Bush spoke at MCT Industries near Albuquerque in May 2003 and praised Sandia's partner as a small business role model. Among other things, MCT manufactures custom trailers, including one developed by Sandia to safely transport obsolete chemical munitions.

transfer to space. These will be the first MEMS devices to fly in space and perform a function.

SMALL BUSINESS PROGRAMS

The New Mexico Small Business Assistance Program (NMSBA) provides technical or business assistance to small businesses to support the growth of the New Mexico economic base. Sandia is eligible to credit up to $1.8 million of funds by providing New Mexico small businesses services such as technical consultations, technical/business training, testing, or access to specialized equipment/facilities. Since the program's inception, Sandia has participated in more than 700 NMSBA assistance projects. For each dollar spent per assistance project, 98 percent was recovered by the state through income taxes within just the first year.

SANDIA SCIENCE & TECHNOLOGY PARK

Sandia National Laboratories was the driving force behind the creation of the 200+acre Sandia Science & Technology Park (SS&TP), a technology community located adjacent to the Labs in Albuquerque. Sandia serves as the Park's anchor, offering companies access to Sandia's scientists, engineers, technologies, and cutting-edge facilities, including the Microelectronics Development Laboratory, Robotic Manufacturing Science and Engineering Laboratory, and Advanced Manufacturing Processes Laboratory.

The SS&TP is a partnership tool, supporting joint research and development efforts, technology commercialization, business development, supplier relations, and economic development. Fifteen companies are currently located in the Park, most in a formal partnership with Sandia. One of these companies is licensing solar cell technology from Sandia for use in the satellite industry. Another is licensing vertical cavity surface emitting laser (VCSEL) technology, and a third is licensing transceiver and transponder technology for the telecommunications industry. Other tenants have CRADAs in place with the Laboratories.

Technology transfer relationships between Sandia and Park tenants have brought over $17 million into Sandia through funds-in and in-kind service agreements since the Park's beginning in 1998. Former Sandians founded three of the Park's companies using spin-off technologies from Sandia. In addition, the Park is the location for two of Sandia's nine strategic suppliers, making it easier for Sandia and these suppliers to interact on a daily basis. The Park has been widely recognized as a model for public/private partnerships.

Some of the buildings in the 200-acre-plus Sandia Science and Technology Park, which celebrated five successful years in business in 2003.

Nuclear Weapons

GUARDIANS *of our* NUCLEAR ARSENAL

Sandia's nuclear weapons work preserves our national security and technological superiority, providing overwhelming technological advantages that often apply in many homeland defense and other national security applications.

Only the most advanced and failsafe technologies, processes, and validated systems fulfill our responsibilities to the nation to ensure the safety, security, and reliability of our nuclear arsenal. Our research laboratories and facilities for large-scale testing and computational simulation are national treasures, and we have now received approval to build a sophisticated Microsystems and Engineering Sciences Applications (MESA) complex, the cornerstone of 21st century weapons development. The National Nuclear Security Administration (NNSA) has also supported other new facility construction efforts and infrastructure revitalization that will establish new science and technology foundations, revitalize our current strengths, and modernize our longstanding capabilities for weapons integration and certification.

Ultimately, our nuclear deterrent lies in the scientific and technological capabilities of Sandia's people and their ability to develop science, technology and engineering solutions to national security problems with the highest degree of confidence.

With each new generation of scientists and engineers entering Sandia, we are determined to build on our advances in innovative ways. We preserve the wisdom, art, and science of our pioneers through the Knowledge Preservation Project, the Weapons Intern Program, and the willingness of more senior Sandia staff to serve as mentors.

★ ★ ★

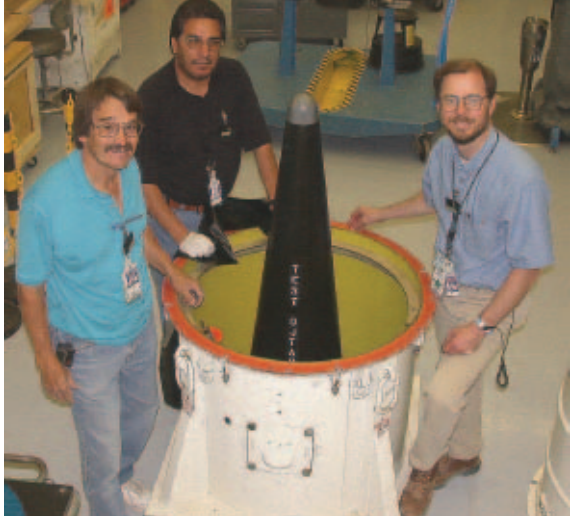
Tom Hunter
Senior Vice President
Defense Programs

NUCLEAR DETERRENT REMAINS STRONG

Sandia is first and foremost a steward of our nation's nuclear weapons stockpile. A failsafe nuclear deterrent has long been vital to minimizing our nation's vulnerability to attack, and Sandia is central to keeping the deterrent ever ready.

Certifying and preserving the nuclear weapon stockpile remain our primary missions, and they continue to evolve due to changing defense strategies and the increasing worldwide proliferation of nuclear and other weapons of mass destruction in a post-Cold-War political environment.

Sandia's Lab Director C. Paul Robinson recently conveyed to the Secretaries of Energy and Defense his eighth annual assessment of, and confidence in, the continued safety and reliability of the U.S. nuclear weapon stockpile. The two secretaries integrate assessments from several sources into an annual stockpile certification statement to the President. Our technical staff support these actions with thorough work throughout the year to maintain the stockpile and to assess its continued capability. Sandia's work has earned an Outstanding rating from DOE for many years in its annual assessment of national laboratories. Further confirmation of this outstanding performance is provided in the following subsections which summarize key elements of Sandia's Stockpile Stewardship efforts.

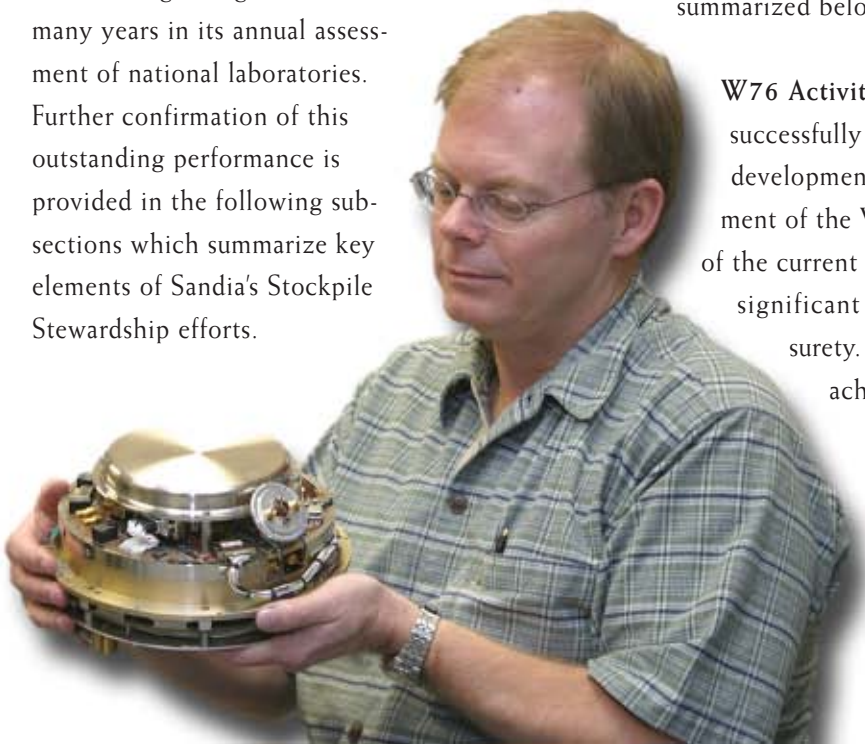


Members of the W76-1 Stockpile Life Extension Program staff responsible for assembling flight test units include (from left) Reyes Chavez, Jimmy Aldaz, and Shawn Kerr.

REFURBISHING AND SUSTAINING WEAPON SYSTEMS

The W76, W80 and W87 Stockpile Life Extension Programs (SLEPs) challenge Sandia to achieve technical innovations and employ new modeling, simulation, and testing tools and capabilities. Sandia is developing new designs for the electrical systems, neutron generators, gas-transfer systems, and several new structural components. We also are working constantly to maximize nuclear surety systems. Sandia designs and validates new War Reserve (WR) quality components that employ technologies that are highly reliable. Additionally, as part of our annual certification process, we are continually evaluating component, subsystem and system performance, and where potential issues are uncovered, we are moving rapidly to address the problems. Notable activities for critical weapon systems are summarized below.

W76 Activities: The W76-1 SLEP team successfully completed its second year of development engineering. The refurbishment of the W76 not only extends the life of the current system, but also incorporates significant improvements in weapon surety. Several significant milestones achieved this year include:



Rex Eastin displays a new telemetry subassembly for the W76-1 joint test assembly, JTA1. It is less than two-thirds the size of its predecessor. The compact design allows more data to be obtained from fewer test flights.

Richard Fitak runs tests with the W80 Command Disable System Tester that will be used at the Pantex Plant. Sandia engineers and technicians designed and built the tester.

- Critical reviews of requirements for the arming, fuzing, and firing subsystem and Joint Test Assembly conceptual designs were performed.
- Two reentry body validation tests were completed and our first Joint Ground Test in support of structural and thermal model validation and environmental specification was conducted.
- Our first flight test bodies were delivered in support of the Navy.
- A neutron generator was redesigned and qualified for the W76 warhead to provide additional surety in radiation environments.

This intensive two-year project successfully supported the stockpile needs without the benefit of underground tests. The W76 neutron generator is the first neutron generator developed and produced at Sandia and installed in the stockpile.

- The W76-1 Arming and Fuzing Subsystem (AFS) integrates radar, flight computer, and diagnostics in a single compact assembly. The design is meeting aggressive cost goals through use of commercial off-the-shelf parts, innovative packaging, and automated production processes. The project team has delivered the first two AFS flight test units on schedule.

W80 Activities: The W80-3 SLEP team successfully completed its second year of development engineering, including recovering from a five-month congressionally mandated work stoppage, and is rebaselining the project timeline and budget. The refurbishment not only extends the life of the current warhead, but also incorporates significant improvements in weapon surety. The W80-3 refurbishment also represents an in-depth collaboration with the Advanced Simulation and Computing (ASC) program to develop and

W80-3 system abnormal environment drop test was completed at Sandia's drop test facility.

implement a model-based approach to qualify a refurbished warhead. Recent major activities and accomplishments include:

- The draft Military Characteristics (MC) document has been completed. It will be reviewed by the W80 Project Officers Group and then forwarded to the Nuclear Weapon Council Safety and Standing Committee for approval.
- Compatibility Documents (CDs) have been released for major components, and the COTS (Commercial Off-The-Shelf) parts list was released to commence the Life of Program Buy activities.
- Both mechanically functional and "bread-board" hardware are now available. With this hardware, several major test activities have commenced, including:
    - System level surety assessment activities
    - System level electrical test series to evaluate interface compatibility
    - System level mechanical test series to update the W80-3 Component Environmental Specification, coupled with simulations using the ASC code SALINAS
    - First hydrodynamic test using W80-3 hardware, to assess the effect of design changes and to measure neutron generator standoff, coupled with simulations using the ASC code ALEGRA
    - First system level abnormal environment (drop) test, coupled w/simulations using the ASC code PRESTO

W87 Activities: The W87 SLEP has required Sandia to redesign several components with new technologies, as the old technologies, long out of production, were cost-prohibitive to restart today.

David Clements and Beth Connors test a B61-4 trainer using an aircraft monitor and control package that simulates the electronic control system of several types of military aircraft. These improved trainers have been distributed to military bases for use by flight-line ground crews in practice drills.

B61 Activities: Sandia also completed several alterations on B61 weapons located outside the continental United States that enhance the safety, use control, and reliability of these retrofitted weapons. Other significant accomplishments include retrofits to allow recoding capability using no-knowledge, end-to-end encryption with the Code Management System; characterizing the glass-to metal seal in the lightning arrestor connectors; and qualifying a powder coat process to replace liquid paint. These projects were supported by hundreds of people across the complex. In addition, a high fidelity trainer was provided to the Air Force to allow training with the full range of new features without the safety or security risks of using real weapons. Finally, Sandia completed a feasibility and cost study for the B61 spin motor replacement. The spin rocket motor is a pyrotechnic propulsion device that rapidly spins the bomb after aircraft ejection. The purpose is to provide aerodynamic roll-stabilization as well as proper spin-acceleration for environmental trajectory sensing. This component replaces an aging predecessor and will be installed in all modifications of the B61 family; work to replace the existing spin motors was scheduled to begin in late 2003.

DESIGNING AND MANUFACTURING WEAPON COMPONENTS

The U.S. nuclear weapon stockpile requires exact engineering and the integration of nuclear weapons with their delivery systems. Sandia researches, designs, and develops more than 90 percent of the 3,000 to 6,500 components of a modern nuclear weapon. And we preserve the nation's capability to develop—should the need arise—new nuclear options for national defense. Sandia is also responsible for most areas of testing systems and training military personnel how to handle weapons safely and securely.

Annie Nickerson places power supply fixtures for neutron generators into a drying oven at Sandia's neutron generator production facility.

With the closure of some of the production agencies in the Nuclear Weapons Complex, Sandia has taken on the additional role of manufacturing to replace capabilities lost when the Pinellas and Mound facilities closed.

In 1993, Sandia was assigned production responsibility for a dozen technologies in what became the Concurrent Design and Manufacturing (CDM) Program. CDM began delivering explosive, electronic and power source components such as gas generators.

In 1994, neutron generator production at Pinellas stopped and Sandia was given the neutron generator production mission. Sandia built a neutron generator production facility and produced its first War Reserve neutron generator in 1999.

Since 1993, CDM has delivered more than 60,000 complex components that must function with highest integrity. For the past three years CDM has achieved a 100 percent first-time acceptance by the National Nuclear Security Administration. Neutron generator production has delivered re-certified and newly manufactured generators on schedule with 100 percent acceptance since 1996.

MICROTECHNOLOGY AND MESA

Sandia is working on new technologies that will radically change weapon design and manufacture. For some time we have explored microsystems technologies to enhance existing systems and enable new system architectures. In May 2003, the Sandia Microsystems and Engineering Sciences Applications (MESA) project received official approval from DOE to begin construction of its Microfab, Microlab, and Weapons Integration Facility (WIF)—the buildings that constitute MESA proper. The formal groundbreaking ceremony, attended by NNSA Administrator Linton Brooks, Sen. Pete Domenici (R-N.M.), Sen. Jeff Bingaman (D-N.M.), Congresswoman Heather Wilson (R-N.M.), and other dignitaries was held in August 2003.

Sandia has been authorized to spend $113 million of the project's $462.4 million funding to prepare the existing building systems and the site's utilities. Construction of the Microfab and Microlab are under way. The construction firm for the Microfab intends to subcontract 82 percent ($44.4 million) to New Mexico based businesses and 30 percent ($16.3 million) to small businesses

including disadvantaged, Hub Zone, and woman-owned firms.

Sandia's largest construction project ever, MESA is expected to fashion a new, more effective way of working together for analysts, weapons designers, and microtechnologists. Among its goals is to hasten the day when microstructures perform effectively in high-surety situations. Current notable accomplishments in these areas are highlighted below.

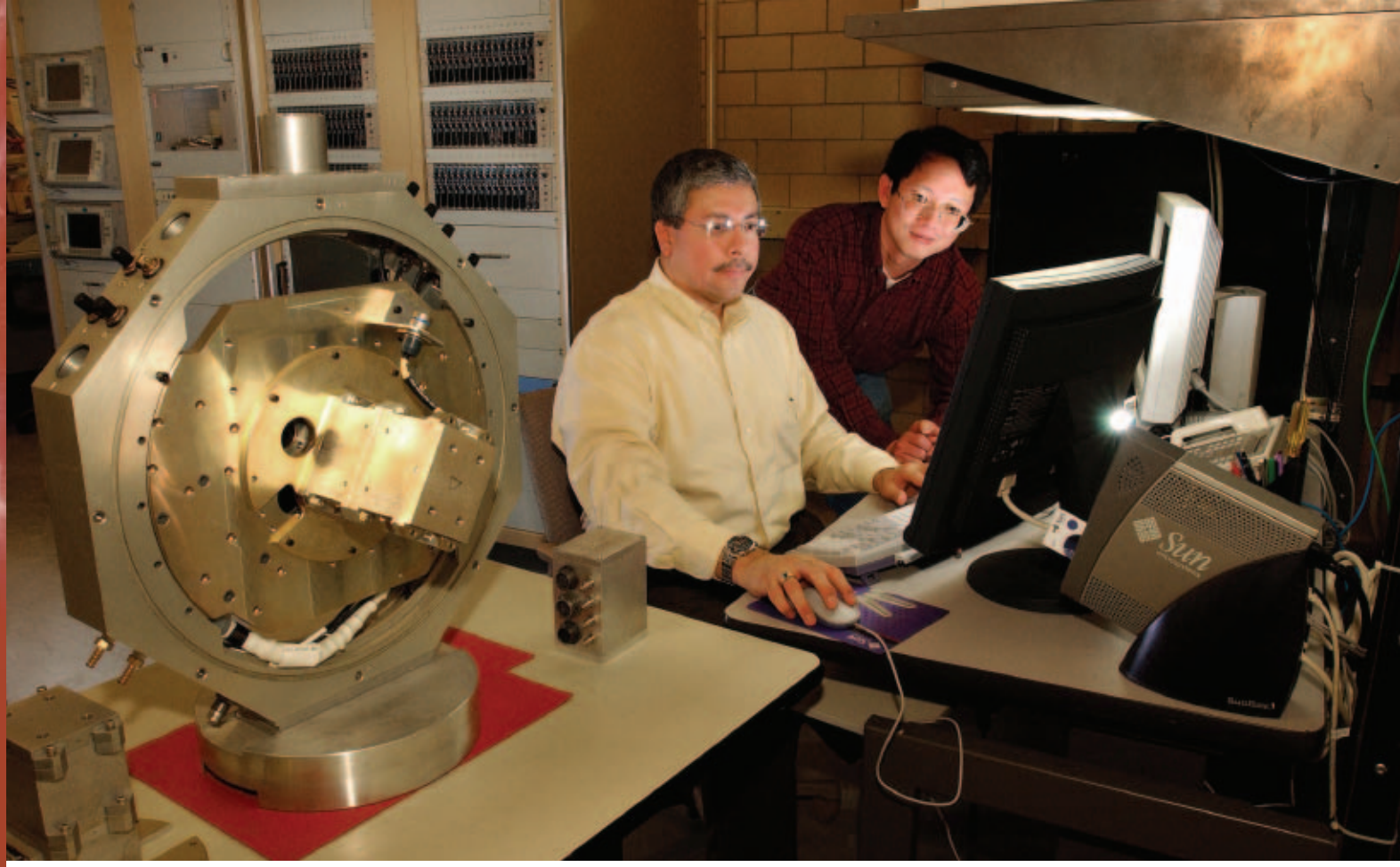
- Sandia delivered two "DOE Accepted Diamond Stamped" application-specific integrated circuits (ASICs) for two weapon systems. These are the sixth and seventh shipments of mark-quality ASICs manufactured at Sandia's MDL, demonstrating Sandia's continuing capability as a supplier of WR quality ASICs for high-reliability DOE weapon applications.

- Sandia developed the first microtechnology-based surety components that we expect will ultimately be introduced into the stockpile. Notable efforts demonstrating a LIGA spring enabled the development of an Environmental Sensing Device (ESD) that can accurately sense low levels of acceleration. (LIGA is a German acronym for lithography, electroplating, and molding). The motion of the ESD spring and sense mass is fluid damped to assure smooth, long-term operation. This robust device is designed to play a key role in nuclear weapon safety architectures that use environmental sensing as part of their nuclear safety theme.

- The Compound Semiconductor Research Laboratory (CSRL) has built photoconductive semiconductor switches (PCSS) that are baselined for use in the W80 program as a fireset trigger. The PCSS fireset trigger replaces a vacuum tube, lowers the parts count and saves space. The PCSS is a gallium-arsenide based electrical switch that is triggered with a laser diode. The PCSS will be built in the CSRL with standard semiconductor batch fabrication methods.

Below: NNSA Administrator Linton Brooks at the August 2003 groundbreaking ceremony for MESA said it is "more than a technological achievement" and will help attract the next generation of scientists and engineers to continue national security work.

Left: Rendering of the Microsystems and Engineering Sciences Applications (MESA) complex that is under construction at Sandia. MESA is the Labs' largest-ever construction project. When completed, the 391,000-sq.-ft., three-building complex will house about 650 researchers.



Oscar Hernandez (left) and Biu So review weapon component data. They are involved in designing and building testers that will be used at the new Weapons Evaluation Test Lab at the Pantex Plant.

STOCKPILE EVALUATION

The Sandia Stockpile Evaluation Program is focused on maintaining a timely, cost-effective stockpile evaluation program that minimizes defect detection time and maximizes data collection, retention, and accuracy. The program has a key role in fulfilling Sandia National Laboratories' and NNSA's stockpile stewardship responsibilities. We are the independent assessors of nuclear weapon surety, performing assessments of the safety, reliability, and quality attributes of nuclear weapons and weapons systems. A core function of the program is to evaluate weapon system attributes, design, and production to ensure that Sandia appropriately addresses the surety and quality of nuclear weapons in the War Reserve stockpile used by the military services. The program also assists Sandia design teams in surety disciplines in the realms of data reporting, statistics, test equipment, and test operations. This inclusive set of disciplines interfaces extensively with research, development, design and production teams across Sandia and the NNSA complex.

Every year 11 weapons are randomly selected for annual testing from each of the nine enduring stockpile systems. Eight of the 11 weapons systems are typically sent to Sandia's Weapons Evaluation Test Laboratory (WETL) at the Pantex Plant near Amarillo, Texas, where they undergo more than 700 tests on automated testbeds. Testbeds replicate the configuration of a weapon as closely as possible. A new generation of testers can conduct tests of three different weapons systems, rather than one, reducing operational and maintenance costs while expanding the scope of the tests. To ensure that Sandia's evaluation activities are sustained into the indefinite future, we are upgrading our infrastructure and physical facilities; the current 40-year-old WETL structure is scheduled to be replaced by a new 30,000-sq.-ft., $22 million facility. Notable activities include:

- A group of California weapon interns successfully designed, built, and launched a highly instrumented W87 warhead—Instrumentation Development Flight (IDF-3). While serving as a real-world weapon-training project for the

interns, IDF-3 allowed Sandia to test some 10 different experimental technologies, including a broadband transmitter, a wireless system bus, a distributed transmitter, and two separate attitude and trajectory measurement systems. IDF-3 contained the first LIGA microsystem to fly on a warhead in a true test flight environment.

- A full-scale B-61 experiment in an Air Force transonic wind tunnel provided laser vapor images of the vortices formed by the weapon's spin motor plume and its interactions with the B61 fins. The data was used with flight test data, experimental research results, and ASC fluid dynamic code predictions to construct a credible simulation-based capability for predicting spin rates and other component functions across the delivery envelopes for each B61 system.

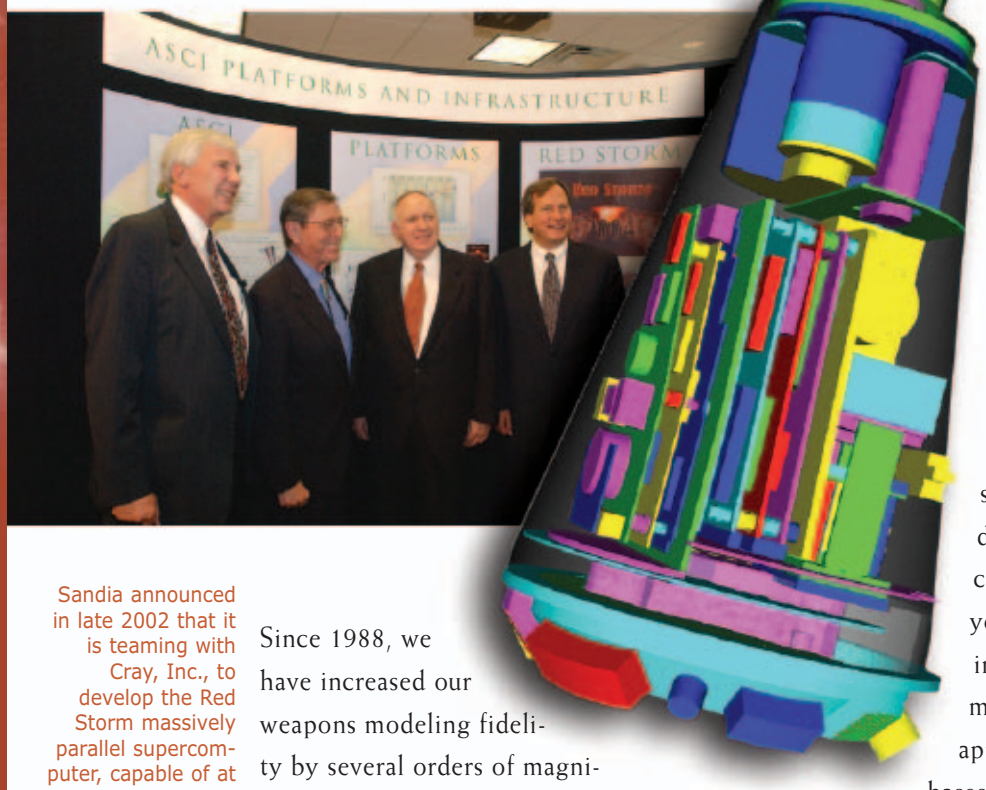
- A new high-G shock test method using the Sandia rocket sled track was invented, developed, and qualified by Sandia for assessing weapon component subassemblies for survivability in penetration environments. The test capability will enable Sandia to respond quickly and less expensively to future weapon requirements. Both W87 and B83 subsystems have been tested against the simulated hard target penetration shock delivered by this novel test method. A second method to test full systems impacting concrete targets under controlled impact conditions is currently under development.

- The rocket sled track was also used, in support of the NNSA Office of Transportation Safeguards, to conduct a full-scale test of an armored tractor and safeguards transporter. This test quantified transporter performance in a severe accident. The transporter retained all cargo items.

Lyndon Pierson (left) and Perry Robertson examine a video encoder/decoder that allows users to work interactively with others thousands of miles away. It is expected to find many uses in the nuclear weapons complex, the military, universities, and industry.

COMPUTING, DATA AND PROCESS MANAGEMENT

Sandia recently brought strong new computing and infrastructure support capabilities online, many of which are enabled by the Advanced Simulation and Computing (ASC) program. When our new Red Storm machine is completed in 2004, Sandia will again have one of the world's fastest computers, capable of a theoretical peak performance of 40 trillion or more operations per second, or 40 teraops, with the potential to reach 100 teraops. To assure the integration and alignment for the supporting information architecture, the Nuclear Weapons Information Environment (NWie) initiative has been created. In its second year, NWie has already made notable advances in organizing weapons-critical data and in providing a strategic roadmap for advancing design-through-analysis processes critical to the weapons complex.



Sandia announced in late 2002 that it is teaming with Cray, Inc., to develop the Red Storm massively parallel supercomputer, capable of at least 40 trillion operations per second. From left are Sandia President C. Paul Robinson, Sen. Pete Domenici, NNSA Administrator Linton Brooks, and Cray chairman and CEO Jim Rottsolk.

Sandia received the 2002 Gordon Bell Award for computational efforts using the SALINAS transient dynamics tool. The weapon model applied in this work is seen here.

Since 1988, we have increased our weapons modeling fidelity by several orders of magnitude. With its unique balance between scalar and vector computing, Red Storm will increase this fidelity even more. We are building a Scientific Computing Facility that is engineered to accommodate the machine's cost-efficient scaleability. Modeling and simulation, in combination with above ground non-nuclear testing in our refurbished test facilities, are emerging as the keystones to certifying the stockpile without nuclear testing.

Sandia's computational tools being developed through the ASC program have received recognition in the international community. The massively-parallel structural dynamics simulation code, SALINAS, received the prestigious 2002 Gordon Bell Award in the category that recognizes "innovative techniques to produce new levels of performance on a real application." The SALINAS team demonstrated sustained aggregate performance of 1.16 teraflops on 3,375 processors of LLNL's ASCI White platform. The tool is being used for design and qualification activities for the W76 and W80 programs.

The enhanced computing environment is enabling many improvements in the systems and processes needed to maintain the stockpile; some of the more noteworthy improvements are:

- Stockpile evaluation and weapons systems personnel are verifying that design intent is satisfied for critical components by drawing upon many years of testing information and matching that data with original design documentation. Discoveries from this approach, which rely on electronic databases for analyses that were previously not practical, are leading to improvements in evaluation and design practices. Continuing projects will further expand the utility of surveillance data systems by using corporate computing capabilities to integrate even more databases.

- The Engineering Bill of Material (EBOM) software application began production use. It is the official Nuclear Weapons Complex (NWC) system to manage the way that materials, parts, components, subassemblies, and assemblies fit together to form a product. It also records Engineering Authorizations for NWC products. EBOM is based on a commercial data management application, and it replaced an outdated, internally developed system.

- Model Based Performance Analysis is using modeling and simulation to better understand weapon electrical system variability and how aging of materials and electrical devices can affect system performance and weapon life-

times. Sandia's powerful circuit simulators ChileSPICE and XYCE, coupled with the CPlant computational platform, have been used to perform the hundreds of simulations necessary to thoroughly investigate potential electrical system and component problems. Studies have been completed on the W80 warhead and are under way on the B61 and B83 bombs.

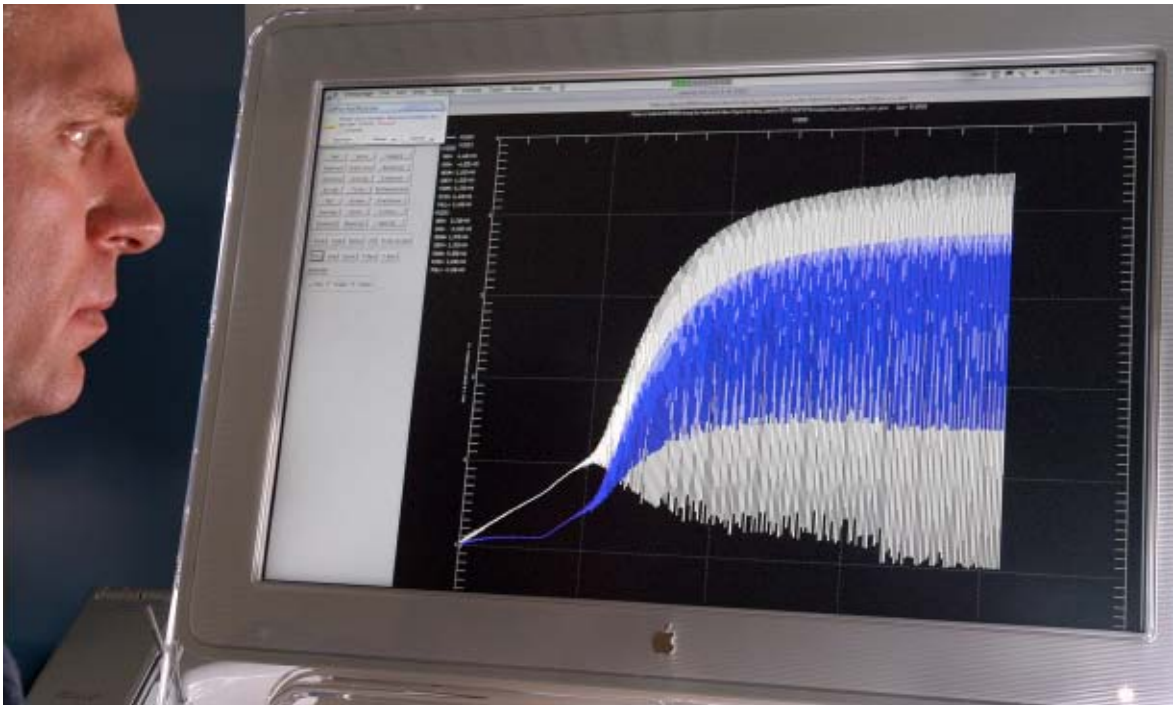
- The Engineer Authorization (EA) Website, built for the Sandia engineer but designed for the NWC community, has reduced the number of document and processing errors, improved data integrity, and reduced the overall release time of Engineering Authorizations from three weeks to two days. The EA Web application is an authoring tool used by weapon engineers to create, edit, and release EAs. Today, it supports more than 300 authors.

- Nuclear weapon reliability departments at Sandia have developed a set of tools and processes to support the evolving stockpile stewardship mission. The Reliability Assessment Model (RAM) software tools allow analysts to efficiently manage complex reliability analysis information and assess aging and reliability impacts on a weapon serial number basis. The RAM tool process allows for automated data updates to reflect ongoing stockpile activity and to quickly meet the information needs of the Department of Defense, NNSA, and Sandia organizations.

WORLDWIDE NUCLEAR SECURITY

Sandia-developed nuclear weapon surety capabilities, addressing every scenario of threat in a systematic way, have been extended to other threats to the nation. We are applying technologies, principles, and systems developed at Sandia for nuclear surety into much broader national security applications.

As an outgrowth of efforts to protect U.S. military assets from terrorist threats, we examined alternative designs of radiological dispersal devices (RDDs) using explosives, mechanical spray, and other novel approaches. A risk-based systems



Scott Hutchinson studies computer simulation of a voltage waveform from an oscillator circuit. Such simulations take good advantage of Sandia's "home-grown" XYCE software, an electrical modeling code used extensively in various nuclear weapons applications.

Doug Clark demonstrates hardware components of the new hardware/ software-based Code Management System, which updates processes and systems that control weapon use.

analysis laid out the RDD threat from end to end—from terrorist motivation; to acquisition of radioactive material; to design, fabrication, and testing of the RDD; to target selection and final weapon delivery and dispersal. The analysis identified immediate security requirements as well as several areas where better understanding is needed.

The DOE Accident Response Group provides worldwide, professional, accurate and timely technical support in resolving accidents and significant incidents involving U.S. nuclear weapons. A new system, Digital-Portable Integrated Video System (D-PIVS), has been deployed. The system provides accident site personnel with four channels of real-time secure video and audio of accident-site events. It can be linked via secure satellite communications to strategic command posts and national emergency response home team facilities.

The Security Matrix Project, jointly sponsored by DOE and DoD, completed its fourth year of work. Project findings for the Navy, Air Force, and DOE operations inside the U.S. are being used to focus attention on improvements to the stockpile during refurbishments and on improved security policies and postures where appropriate. Analysis of data collected at overseas locations will be conducted soon.

SITE STEWARDSHIP

Sandia takes its site stewardship responsibility as seriously as its role in stockpile stewardship, executing substantial site planning and capital investment efforts to keep the site viable and responsive to mission needs now and in the future. The annual Ten Year Comprehensive Site Plan describes the accomplishments and future plans for capital investments in new and renovated facilities and utilities, as well as demolition of outdated facilities. These site investments are accomplished through line items, general plant projects, renovations, and facilities and infrastructure recapitalization program funds, and are carefully incorporated into Sandia's budgeting process to fulfill its site stewardship role.

The Distributed Information Systems Lab, under construction at Sandia/California, will be one of several new key facilities that will be used in the Advanced Simulation and Computing Program for modeling and simulation-based stockpile stewardship.

Nonproliferation and Assessments

MAKING *the* WORLD *a* SAFER PLACE

Sandia's Nonproliferation and Assessments (NP&A) program provides enabling systems, science, technology and expertise to reduce the threat to the United States from the proliferation and use of weapons of mass destruction. It also provides performance and vulnerability assessments of both U.S. and foreign technical capabilities and associated assessment tools and technologies.

The NP&A program is vital to U.S. National Security and for global security because of the confluence of the advances in technologies for developing biological, as well as chemical, nuclear and even unconventional weapons; the excess nuclear material from reduced weapons arsenals in the Former Soviet Union (FSU); and the willingness of terrorists to inflict mass casualties in attacks against the U.S. and its allies.

The NP&A program supports U.S. policy worldwide in its efforts to reduce the stocks of excess nuclear materials and to protect existing stocks of nuclear materials, including in the FSU. We also support verification and monitoring efforts associated with detecting and controlling the proliferation of weapons of mass destruction, including the development of new technologies for ground, aircraft, and satellite deployment. The physical-protection systems that we are developing and evaluating include technologies deployable at home and abroad. Much technology developed in the NP&A program is also broadly applicable to the homeland security efforts. This includes technologies to detect and impede terrorists' activities as well as to protect critical infrastructure.

Al Romig in front of a giant image of a Sandia micromachine gear. The tiny devices may play a huge role in future Sandia technologies.

The NP&A program supports one of National Nuclear Security Administration's strategic goals, to "detect, prevent, and reverse the proliferation of weapons of mass destruction while promoting nuclear safety worldwide." Although significant progress has been made, particularly in improving the protection of material in the FSU, the national security requirements for efforts to combat weapons of mass destruction will be of the highest priority for the foreseeable future.

★ ★ ★

Al Romig
Vice President
Nonproliferation and Assessments

NEW TECHNOLOGIES FOR DETECTING PROLIFERATION ACTIVITIES

Sandia offers a full-system approach to addressing the problems associated with the proliferation of technologies that enable production and use of Weapons of Mass Destruction (WMD.) Sandia maintains capabilities for threat assessment and signature modeling to allow identification of measurable phenomenology associated with mal-intentioned activities. Technologies necessary to advance sensor and sensor systems are developed and matured to levels necessary for system implementation in both utility demonstrations and operational implementation. Sandia also maintains a robust system analysis capability to understand and evaluate system effectiveness, vulnerabilities, and possible application to new functions. Enhanced science-based data analysis, data fusion, and data exploitation are important to all proliferation detection activities.

The technologies Sandia develops range from microscopic in situ instruments to large remote sensing systems that monitor the globe. Miniaturized instruments are virtually impossible to detect or compromise and include sensors that detect substances or events, such as the movement of weapons materials, and communication and tracking devices. Worldwide systems gather data from a vast array of sources and intelligently fuse these data streams into information that helps develop knowledge needed for strategic decision-making.

The U.S. Nuclear Detonation Detection System (USNDS) completed another successful year supporting the Department of Energy's National Nuclear Security Administration's (DOE/NNSA's) nuclear treaty verification mission. Our payloads on the Defense Support Program (DSP) and Global Positioning System (GPS) satellites have performed without a mission-critical failure for more than 30 years. These payloads provide global monitoring for atmospheric and space nuclear events. Sandia also supported three new launches this year.

The USNDS-fielded ground system consists of both fixed site resources and ground mobile resources. The system met all performance goals this year. Design of the next generation ground system was completed and the development effort entered the implementation phase. This is the largest software development ever undertaken by Sandia and utilizes state-of-the-art software engineering processes. The new system will receive data from all existing on-orbit satellites plus the next-generation GPS satellites and sensors. This real-time data processing and display system supports detailed satellite state of health monitoring and performs all data analysis functions necessary for the nation's nuclear weapons treaty monitoring mission.

Sandia and other NNSA lab payloads have performed without a mission-critical failure for more than 30 years on satellites involved in defense surveillance missions, including Defense Support Program satellites operated by the Air Force Space Command. (Illustration courtesy of U.S. Air Force.)

The Sandia-developed Advanced Atmospheric Research Equipment (AARE) will enable the Air Force to continue a 50-year-plus mission of monitoring foreign nuclear tests. AARE will provide a

Artist's illustration of Sandia's Multispectral Thermal Imager (MTI) satellite and sensor system that completed its primary three-year research goals in 2003. However, it continues collecting images for several government agencies.

Multispectral Thermal Imager (MTI) satellite view of Mt. Etna taken above Italy several years ago. Huge lava flows can be seen beneath the smoke and clouds.

unique capability to do treaty monitoring and sampling against worldwide nuclear testing activities. This system replaces an Air Force airborne nuclear debris collection and analysis system using 30- to 40-year-old technology. AARE uses modularized systems that can be deployed on any of three designated Air Combat Command TC-135 training aircraft, saving considerable operational costs for the Air Force.

The DOE/NNSA Multispectral Thermal Imaging (MTI) satellite project is exemplary of the immeasurable technological capacity of the national laboratory complex. In a joint laboratory effort, the Sandia and Los Alamos National laboratories and the Savannah River Technologies Center worked with multiple elements of the Department of Defense, industry, and academia to demonstrate the utility of space based high-resolution multispectral thermal imagery. The MTI's telescopic camera captures imagery data in 15 spectral bands extending from the visible to the infrared at levels of radiometric accuracy never previously accomplished from space. Many of the baseline critically enabling technologies for modern and future spectral imaging systems have been proven by the MTI team.

Sandia designed and built the MTI satellite, and we operate and maintain the system that has now completed its third year on orbit, surpassing its system specification of 18 months. The system has collected more than 5,300 multispectral data sets for a wide variety of government customers including NNSA, military, and civilian organizations.

Sandia's MTI data exploitation team continues to develop definitive new spectral image processing techniques. Because of the important role these techniques may play in improving image analyst performance, we expect many of these Sandia tools

This Sandia satellite-based optical sensor package, only 1.5 cubic inches, provides a revolutionary level of processing. Sensing and signal processing are done at the equivalent speed of more than a gigabit per second, a level never before approached in a package this small.

will be incorporated into future operational production systems.

A Sandia team completed design, fabrication, and flight qualification of an innovative 3-dimensional, miniaturized optoelectronic sensor package for use in satellite applications. In 1.5 cubic inches, its revolutionary architecture provides for optical sensing, signal conditioning, and signal processing at the equivalent speed of a gigabit per second, a level of performance never before approached in a package within this volume. The package was integrated into the next level of assembly and delivered for a scheduled launch in late 2003.

The AURA (Advanced UV Remote-Sensing Applications) ultraviolet laser-induced fluorescence lidar payload, designed for deployment on an unmanned aerospace vehicle (UAV), successfully detected a variety of biological warfare agent simulants in tests at Dugway Proving Ground, Utah. The AURA system successfully discriminated multi-scenario tests involving both bio and non-bio releases. The program also developed Ares, a new ground-based portable ultraviolet laser-induced fluorescence lidar, for protecting high-value facilities or high-visibility events.

Sandia successfully completed Phases 1 and 2 of the Nuclear Explosion Monitoring Vision 2015 Study. This project explores technology the Air Force Technical Application Center (AFTAC) will need in 2015 to carry out its mission of global monitoring of nuclear testing. The systems studied include satellites, seismic stations, and other monitoring assets.

WORKING WITH THE FORMER SOVIET UNION

Sandia first became significantly involved in international nuclear material and weapon security in the early 1990s by helping to protect Russian weapons through the Cooperative Threat Reduction (CTR) program. This involvement drew upon Sandia's knowledge of nuclear security, having held for many decades, the primary responsibilities for developing and implementing security for the entire U.S. weapons complex. Sandia has expanded its nuclear nonproliferation and combating terrorism mission through its efforts to rapidly improve the security of nuclear weapons, weapons-usable nuclear material, technologies and expertise throughout the former Soviet Union (FSU) and other countries.

Sandia has been working in various ways since the early 1990s with Russia in the Cooperative Threat Reduction program. This photo shows a Russian nuclear weapons transportation railcar, modified by U.S.-provided kits to make them safer and more secure. (Photo courtesy of Defense Threat Reduction Agency.)

Sandia has been working with the All Russian Institute of Automatics (VNIIA) since 1997 to develop advanced monitoring technologies for use by the Russian Ministry of Defense (MOD). The TOBOS (from the Russian acronym for Safety and Security Technologies for Russian Warheads) project entered into an important three-year program of realistic field-testing at MOD sites. Phase 1 of the field trials will evaluate the operational performance of advanced Russian-manufactured storage monitoring equipment. Construction has begun on a unique testbed at the MOD's Weapon Safety and Security Technology Research Center in St. Petersburg. Testing commenced in the summer of 2003.

The Second Line of Defense (SLD) program, originally a U.S. and Russian cooperative effort, now includes efforts in more than 20 countries to reduce the risk of nuclear smuggling by deterring, detecting, and interdicting illicit transport of nuclear materials and weapons across borders. By May 2003, the SLD program had performed more than 100 surveys of border crossings in Russia and Newly Independent States and had completed the installation of security and nuclear material detection systems at more than 40 sites. In support of the U.S. Customs Service Container Security Initiative, SLD participants are also surveying and equipping foreign megaports to prescreen U.S.-bound container cargo. Sandia was named the program manager and systems integrator for the DOE NNSA SLD program and implements a systems approach that incorporates threat analysis, site prioritization and selection, and installation and operation of equipment at border crossings including airports, seaports, and land ports of entry.

Sandia assisted DOE/NNSA in developing a strategic plan to secure and control foreign-origin radiological dispersion device (RDD) source materials. The security of foreign radiological material is a new and important part of the DOE NA-25 Material Consolidation and Radiological Threat Response Program because such material could potentially be acquired and used against U.S. interests in a radiological dispersal device or "dirty bomb." Sandia is also supporting related efforts, including the DOE NA-25's collaboration with the IAEA to identify and secure RDD material internationally.

A prototype Mobile Monitoring System for Container Transport (MMCT) has been installed at the Chernobyl Nuclear Power Plant in Ukraine as part of the International Atomic Energy Agency (IAEA) safeguards system. The MMCT documents nuclear material continuity-of-knowledge during the unattended transport operation by means of a set of containment, surveillance, nuclear radiation, and location sensors in an autonomous integrated monitoring system on the spent fuel transport rail car. Sandia was responsible for system integration and teamed with Los Alamos National Laboratory and Aquila Technologies Group to develop hardware and software components.

Sandia hosted the April 2003 Combatting Terrorism Workshop that included 80-some participants from the U.S. and Russia. The countries are collaborating to develop terrorism-detection capabilities.

In the aftermath of the 9/11 attacks, Sandia initiated a dialog between the directors of the U.S. and Russian nuclear weapons laboratories on combating terrorism cooperation. In April 2002, with the endorsement of their respective agency leadership, the directors agreed to begin work immediately to establish a baseline of requirements that would drive the development of detection capabilities under U.S.-Russian collaborative efforts. Consistent with this initiative, Sandia hosted the April 2003 Combatting Terrorism Workshop that included over 80 participants from the six U.S. and Russian labs, as well as representatives from DOE NNSA, Minatom, U.S. and Russian Customs, Department of Homeland Security, and the local first-responder community.

COOPERATIVE INTERNATIONAL SECURITY LEADERSHIP

Sandia efforts help reduce the motivation to acquire or use weapons of mass destruction by enhancing regional stability in parts of the world critical to U.S. national security. Sandia supports a broad range of cooperative international security programs that support U.S. nonproliferation policy globally, including development, implementation and promotion of measures to reduce security threats from WMD proliferation and to verify international nonproliferation commitments.

Sandia's Cooperative Monitoring Center (CMC) in Albuquerque was established in 1994 to support the DOE NNSA's, the Defense Threat Reduction Agency's (DTRA), and the State Department's cooperative international programs in exploring ways that technology can support the development and implementation of security policy and agreements. Recently, the U.S. State Department approved and the DOE sponsored the establishment of a CMC in Amman, Jordan. The CMC@Amman provides a forum for regional training on nonproliferation technologies, developing new monitoring capabilities, monitoring demonstrations, and multidisciplinary interactions among scientists, engineers, and policymakers. The first cooperative monitoring workshop was held at the CMC@Amman during the summer of 2003.

Past and current CMC regional security experience and systems engineering expertise have stimulated U.S. interagency and foreign government requests for Sandia to serve as technical advisor on South Asia border security issues. In this role, Sandia contributed to Deputy Secretary of State Richard Armitage's talking points for his visit to the region during the India-Pakistan nuclear crisis. This expertise also resulted in requests for briefings to ministerial-level Indian and Pakistani officials.

Sandia has some of the world's best and most recognized bomb-disablement experts and technology. Here, Chris Cherry briefs bomb squad members before a live demonstration. Chris and his team regularly conduct bomb-disablement training sessions for civilian and military bomb personnel throughout the U.S.

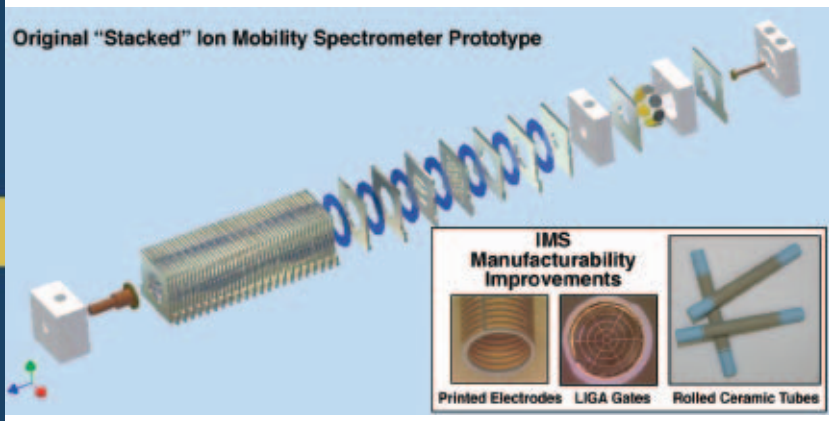
DIRECT MEASUREMENT OF PLUTONIUM

Collaboration between Sandia and Lawrence Livermore National Laboratory is exploring a new way to safeguard fissionable material, by building an antineutrino detector at the San Onofre Nuclear Generating Station in San Clemente, Calif.

In a reactor, uranium in the fuel rods releases six antineutrinos per atom during radioactive decay. As electricity is produced, some plutonium is also created, which releases fewer antineutrinos per atom. By measuring the energy and rate of antineutrinos released, the researchers can watch for anomalies, such as an unexpected change in spectrum after a shutdown.

Antineutrinos are subatomic particles so insubstantial that they pass through most matter without interacting. However, room-sized detectors like the one coming online at the San Onofre plant can detect a small fraction of the huge number of antineutrinos released from the reactor core.

The project measures antineutrinos to show plutonium has not been removed, or is not being produced at an abnormally high rate by modifying the operating parameters of the reactor. The system can also be used to independently measure the plutonium content in a spent reactor core destined for reprocessing or storage. The international regime that currently safeguards civilian plutonium production relies heavily on operator declarations and plant operating history to estimate plutonium content.



ENHANCING PROLIFERATION DETECTION CAPABILITIES

The MicroHound is the first hand-carried sniffer that integrates in a single device Sandia technologies for the preconcentration, sampling, and detection of explosives. The 12-pound sniffer can detect explosives in parts-per-trillion concentrations—sensitive enough to identify explosives in a fingerprint left by a person who had recently been working with bomb-making ingredients, and two orders of magnitude more sensitive than previous, larger models. The MicroHound could be used to sniff out hidden explosives in courtrooms, schools, or other high-risk facilities, or at entry points to screen people or parcels.

Sandia's development of highly sensitive sniffers includes a drive-through vehicle checkpoint and a walk-through portal for screening airline passengers at airports. Sandia has fabricated, assembled, and delivered several MicroHounds for field-testing and evaluation.

Development of a three-inch Ion Mobility Spectrometer (IMS) provided basic functionality for the MicroHound. A new construction method improves manufacturability and reduces part count in the IMS using novel low-temperature ceramic processing techniques and a micromachining process called LIGA, a German acronym for Forming by Lithography and Electrodeposition. The resultant assemblies are repeatable and manufacturable, requiring a fraction of the former man-hours. This accomplishment will facilitate the future deployment of the MicroHound and ease transfer to a commercial producer.

New construction technology developed at Sandia means three-inch ion mobility spectrometers can be manufactured much faster. They are used for detecting trace explosives.

Kevin Linker, one of the developers of Sandia's MicroHound chemical sniffer, displays a unit similar to those being evaluated in 2003 by federal emergency response teams.

MICROHOUND MEETS MICROCHEMLAB

The Surface Acoustic Wave (SAW) sensor proposed for the MicroHound™ captures explosives molecules on its vibrating quartz surface for a fraction of a second and quantifies them by measuring changes in vibration caused by their masses. The sensor relies on a gas chromatograph (GC) column—a tiny silicon tunnel a hair in diameter but more than a meter long in 43 inward spiraling rotations—to separate the chemical species for SAW identification. A polymer coating on the tunnel's inner walls acts like stones in a river, slowing down larger, heavier, stickier objects—in this case molecules—floating in the air stream but allowing smaller, lighter ones to float past unimpeded. At the end of the tunnel, the lighter chemical species arrive first, followed in waves by increasingly heavier and stickier ones.

The SAW sensor uses each chemical type's travel time to determine its identity. The GC-SAW combination already has been demonstrated as part of the MicroChemLab™ to identify chemical weapons agents (see more in next section). Although explosives detection represents an expanded application for the technique, the approach is identical. The GC-SAW takes longer than the ion mobility spectrometer (IMS) to identify an explosives species, but is better at distinguishing among those species.

CHEM/BIO COUNTERMEASURES SUPPORTING HOMELAND SECURITY

Since 1996, Sandia has been working on technologies and systems to address chemical and biological countermeasures. Beginning with the DOE's Chemical and Biological Nonproliferation Program,

Sandia researchers are developing a variety of sensors to provide early warning of chemical/ biological attacks in airports, subways, and other public facilities.

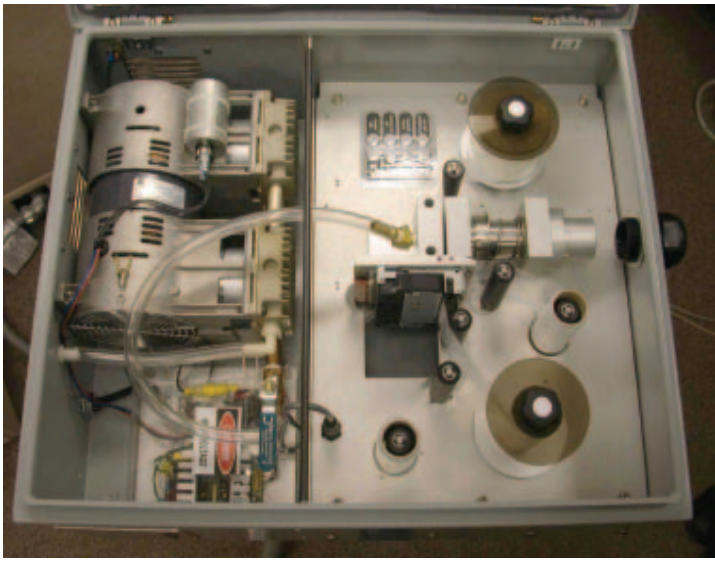
and continuing under the Department of Homeland Security, Sandia has engaged in a broad range of activities to protect citizens from the threat of chemical or biological attack.

Activities at Sandia that are contributing to the success of the new agency include early warning systems to detect danger, operational guidance to respond to an attack and restore vulnerable public facilities, and systems analysis work to assist public agencies train and prepare for civilian defense.

Integrating Sandia's work in chemistry, biology and systems engineering, we are developing advanced detection and analysis systems capable of rapid and sensitive detection of various threat agents for facilities defense and consequence management. MicroChemLabs™, one such technology, are portable, hand-held analysis systems incorporating "lab-on-a-chip" microfluidic technologies for detection of chemical or biological agents.

The MicroChemLab™ Chem Detector System identifies chemical warfare agents and toxic industrial chemicals. It collects and concentrates samples, separates them via a miniaturized gas chromatography column, and detects the constituent components using an array of surface acoustic wave sensors. Accomplishments this year include development and demonstration of methods to detect a broad spectrum of toxic industrial chemicals. In addition, we demonstrated use of our Chemical Warfare Agent (CWA) detectors under real world circumstances at San Francisco International Airport. That unit performed very well over a period of many months and over 80,000 detection cycles.

The MicroChemLab™ Bio Detector System is a laboratory demonstration unit designed for rapid detection of proteins. It has been used to identify biotoxins such as ricin, staphylococcal enterotoxin B and botulinum toxin; it is now enabling identification of viruses and bacteria using protein signatures. This year we demonstrated that the MicroChemLab™ Bio Detector System can be used to acquire unique signatures from viruses and



Sandia has teamed with other national labs to develop innovative airport surveillance technology that uses wireless intelligent modules, early warning detectors, and aerosol bio-detectors such as the one pictured here.

we developed methods to ensure that these signatures are reproducible and robust to variables such as viral culture conditions and sample prep.

This year the Department of Homeland Security (DHS) initiated a project to create a broad-spectrum bioagent detector that is portable and easily concealed, BioBriefcase, through collaboration between Sandia and Lawrence Livermore National Laboratory. The detector will use capillary electrophoresis on Sandia ChemLab platform with three analysis trains; DNA analysis to identify bacteria and viruses; immunoassays to identify bacteria, viruses, toxins; and protein signatures to identify toxins. It should function autonomously to collect and detect samples in a stealthy and easily deployed manner. The BioBriefcase should also be capable of being manned by a minimally trained user to function as a portable laboratory, providing quick turn-around between sample analysis and responsive action.

A domestic demonstration and application project begun this year in collaboration with Lawrence Livermore is intended to create an optimal model for restoring a vulnerable facility, such as an airport, after a biological agent attack. The envisioned model is known as BROOM for Building Restoration Operations Optimization Model. An ongoing National Academy of Science study is exploring the risks posed by three potential biological warfare agents: anthrax, smallpox and plague. Among issues to be decided is the level of decontamination required for safety. (At contaminated Congressional and postal facilities post-9/11, the standard used was zero viable spores, which proved time-consuming and expensive.)

Sandia's traditional strengths in systems analysis and systems engineering are being applied to efforts that will provide specific methods and tools for use in facilities protection, a vital aspect of urban chemical and biological defense. Subways and airports in particular present critical and symbolic targets for terrorism, where relatively unsophisticated attacks can have severe and far-reaching consequences.

Weldon Teague (left) and John Fulton fill a room with a blast-mitigation and chemical/biological/radiological-containment foam that could become a common tool for first-responders who deal with such threats.

Last year, San Francisco International Airport announced a facility protection collaboration with Sandia that recommends preparedness measures for the near term and proves critical elements of chem/bio facility defense. This demonstration and application work has been conducted under PROACT, Protective and Responsive Options for Airport Counter-Terrorism. Work at the airport takes a comprehensive approach to airport facility defense, including vulnerability assessment, tracer

Sandians help install sensors at San Francisco International Airport to better understand how aerosols flow through the facility. The research is being conducted under the PROACT (Protective and Responsive Options for Airport Counter-Terrorism) program.

testing and modeling, facility hardening concepts, biological and chemical detection system testing, response planning, and simulation-based tabletop exercises. These programs are providing a foundation for protecting facilities throughout the country.

Building on our historic responsibilities to assess vulnerabilities of urban populations to chemical and biological attacks, we have been heavily involved in developing architectures for urban biodefense systems. Simulations using tools developed in collaboration with researchers at Stanford University have allowed us to model the efficacy of proposed systems and to optimize specific design features.

An expanding capability is the Weapons of Mass Destruction-Decision Analysis Center. In it, systems analysts created a bioterrorism simulation that

Sandia is working with the Port of Long Beach and the City and Port of Los Angeles as security consultant and project manager for their Operation Safe Commerce program, which aims to improve port security without unduly interfering with commerce.

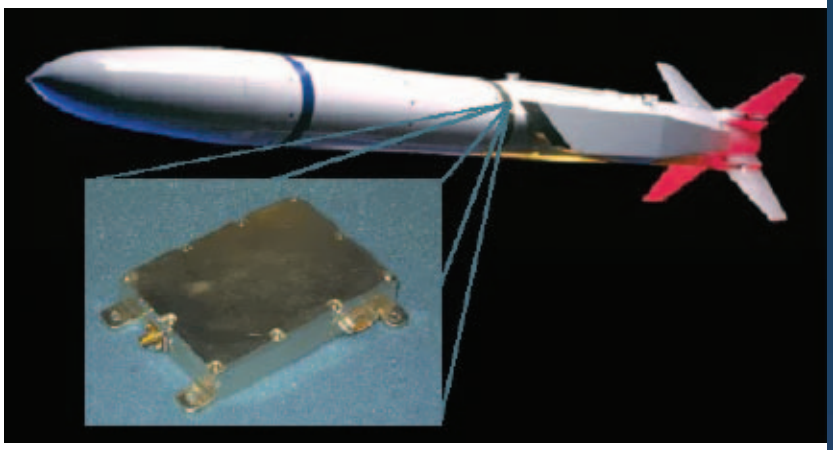
engages the perspectives of many decision-makers as they seek to deal with a complex event that unfolds over days, having to make decisions along the way with incomplete information. By playing through various scenarios, decision-makers can examine various protection and reaction schemes and figure out what works best under different conditions. First featuring a simulated biological attack of the San Francisco Bay Area, the program is now being adapted to address other threats.

DEVELOPING PHYSICAL SECURITY TECHNOLOGY

Sandia has been designated security consultant, systems integrator, and project manager for the Operation Safe Commerce (OSC) – Pacific program with the Ports of Los Angeles and Long Beach. The OSC-Pacific program is an international partnership that involves the public sector (ports of Los Angeles and Long Beach, U.S. Customs, U.S. Coast Guard, and Sandia) and numerous technology providers in the private sector. The program addresses container security as well as the overall supply chain, of which containerized shipments are a key component. Security is monitored from overseas points of origin to final U.S. destinations through the ports of Los Angeles or Long Beach. Sandia analyses support the identification of cost-effective means of addressing the most significant security problems of ports and their supply chains including terrorist attack, illegal immigration, drugs, and nuclear smuggling.

A successful demonstration of the Unconventional Nuclear Warfare Defense (UNWD) Test Bed was held on Kirtland Air Force Base (AFB). This was a combined effort of the Defense Threat Reduction Agency (DTRA), DTRA's contractor, the Washington Defense Team, Kirtland AFB, and a multi-lab collaboration of Sandia, Los Alamos, Lawrence Livermore, and the Remote Sensing laboratories. The UNWD Test Bed is a congressionally directed/funded program to showcase technology for protecting military installations against unconventionally delivered nuclear weapons, improvised nuclear weapons, and radiological dispersal devices.

Operational test and evaluation of the Remote Response Platform, funded by the DOE Office of Security, was successfully completed. This technology provides a weapons platform for security forces for extremely accurate and rapid response, minimizes exposure for security response personnel, and effectively provides force multiplication. Force-on-force and combat simulation evaluations also have been completed with favorable results.



Sandia's spread-spectrum tag, seen in this cutaway on an Advanced Anti-Radiation Missile, can remotely verify whether "hits" are made on missile targets.

Sandia has developed a toolbox of radio frequency communication elements that may play important roles in identifying, tracking, and targeting terrorist activities. We demonstrated the utility of our microtransmitter in a Navy Fleet Battle Exercise. In a recent test at China Lake, our new spread-spectrum tag was used to remotely verify that an Advanced Anti-Radiation Missile made a direct hit on a simulated surface-to-air missile site.

Military Technologies and Applications

HELPING MAINTAIN SUPERIORITY *for our* ARMED FORCES

Jim Tegnelia shows off some of Sandia's robotics technology. Devices such as these have a variety of national security and law-enforcement agency applications.

Sandia National Laboratories has been working to maintain national technological superiority in weapons systems since its founding more than 50 years ago. This superiority is critical in fighting terrorism and equipping our armed forces for future conflicts.

The U.S. military is transforming from a focus on major theater warfare to a force that is responsive, deployable, agile and versatile, with increased lethality, survivability and sustainability. This demands swift, state-of-the-art technology development, the ability to rapidly deploy high-impact systems and transfer advanced technology to industrial production, and a system-of-systems approach. Sandia strengths in basic and applied research, missile defense, surveillance and reconnaissance, robotics, modeling and simulation, and large system analysis and integration are playing a strategic role in this transformation.

The reality of asymmetrical warfare as well as chemical, biological, nuclear, and information warfare poses greater threats than ever to America and nations around the world. Advanced technologies are being developed in an increasing number of nations and by transnational terrorist organizations. But even more advanced technologies can detect, locate, characterize, defend against, and, if necessary, destroy such threats.

Sandia is working hard to develop and field these technologies.

Our mission supports many agencies worldwide in an effort to combat proliferation, attempts at regional supremacy, terrorism, and threats against our armed forces and homeland.

★ ★ ★

Jim Tegnelia
Vice President
Department of Defense Programs

SUPPORTING THE NEW TRIAD

The 2002 Nuclear Posture Review called for a new triad for strategic defense that includes conventional weapons and missile defense. Together with the Quadrennial Defense Review and the Defense Planning Guidance, these documents define a new environment in which Sandia is playing a strategic role.

Because Sandia designed many elements of the nation's nuclear stockpile, it possesses a vast storehouse of knowledge about warhead flight characteristics, as well as various signatures and behaviors. Further, our five-decade role in national security assessments gives us considerable knowledge of adversaries' designs and potential capabilities. Sandia has supported more than 80 full-scale flight tests, principally demonstrations of advanced and exploratory designs. Today, Sandia uses this knowledge to design and build realistic targets and decoys for National Missile Defense tests and target test vehicles for the Navy Theater Wide Missile Defense.

Tonopah Test: F-16 aircraft were used to test impact control technologies for hard-target penetration at Sandia's Tonopah Test Range.

Other missile defense projects that have advanced the technologies:

- Sandia successfully fielded a next-generation inertial navigation system for spinning vehicles in a National Missile Defense test. To meet program requirements, weight and volume were reduced by 50 percent below previous navigation systems.
- Sandia fielded target systems for the West Coast Risk Reduction Flight. These systems featured two new Sandia target designs that provided an opportunity for collection of exoatmospheric infrared and radio frequency signatures.
- Sandia delivered a space-qualified Radiation-Hardened Key Data Processor (RH-KDP) system design to the Air Force NAVSTAR Global Positioning System (GPS) Joint Program Office. General Dynamics Decision Systems has integrated Sandia's design into a Selective Availability Anti-Spoofing Module (SAASM) for space vehicle applications. Sandia is the sole supplier of National Security Agency-endorsed terrestrial and space RH-KDP designs, which implement the SAASM features mandated by the Joint Chiefs of Staff to enhance the security of all future military GPS receivers.

Target objects for the Missile Defense Agency's flight test program are provided by Sandia, which also does lethality calculations and studies national missile defense countermeasures.

DESIGN, TEST, AND BUILD A PENETRATOR FOR US FORCES

Sandia engineers are designing a new conventional weapon that gives U.S. forces a way to penetrate hardened targets quickly, precisely, and safely. Currently the military's options for attacking such targets are limited to aircraft-delivered penetrating bombs—which generally don't reach the needed levels of precision, penetration velocities, or nearly straight-down impact angles. As part of the accelerated three-year effort, Sandia not only will design and develop the new non-nuclear Tactical Missile System–Penetrator (TACMS-P) and flight-test three prototypes at White Sands Missile Range, N.M., it also will produce six battle-ready weapons for immediate inclusion in the Army's arsenal. The six weapons represent the first time a Sandia-fabricated weapon system will directly enter the military's conventional arsenal.

Sandia is designing and testing a new conventional (non-nuclear) weapon for penetrating hardened and shallow buried targets quickly, precisely, and safely. Here Mark Beader (left) and Randy Swier examine an electronics package for the new Tactical Missile System—Penetrator (TACMS-P) weapon.

The Sandia portion of the program requires the mating of an existing tactical weapon design—the Army Tactical Missile System (ATACMS)—with the design of a new warhead developed under Navy guidance. The new systems include actuated fins that provide enhanced maneuverability during flight, advanced fuzing systems that sense depths and underground features, and improved navigation and control systems. The redesigned warhead also will contain a new penetrator—a Sandia-patented cast steel sleeve called the Monolithic Ballasted Penetrator—designed to "shed its skin" as it rumbles through packed earth and concrete

at thousands of feet per second. The penetrator contains insensitive high explosives and a Sandia fuze that will ultimately trigger the warhead and destroy the target. The Navy chose Sandia to develop TACMS-P based on the Labs' proven expertise in high-speed flight system design; precision navigation, guidance, and control; and earth-penetration technology.

Like the ATACMS, a standard ground-to-ground missile in the Army inventory, the TACMS-P will be launchable from the Army's Multiple Launch Rocket System (MLRS) and, following further development, potentially from Navy submarines. The ability to launch penetrators from mobile launchers hundreds of miles away not only removes aircraft from harm's way and provides for greater precision and depths of penetration, it also speeds the time between target selection and weapon delivery to minutes rather than hours, a desirable capability when targeting scenarios change quickly and frequently. The TACMS-P thus provides a capability the Army and Navy need in today's war-fighting situations. The program is co-sponsored by the Army and Navy as an Advanced Concept Technology Demonstration.

Sandia is developing a range of technologies and capabilities to defeat difficult targets. Difficult targets include hardened, deeply buried underground facilities used to manufacture or store weapons of mass destruction. Sandia has combined expertise in advanced sensors, geophysical modeling, and signal processing to develop a prototype integrated model that uses passive seismic, acoustic, and electromagnetic signals for target characterization. The model combines site-specific geological information and sophisticated finite-difference modeling tools to predict machinery and other specific signatures observable at the Earth's surface.

To attack these targets, Sandia conducted a technology demonstration flight test that successfully demonstrated impact control technologies. An F-16 released an inert bomb that flew a controlled flight profile, using a GPS-aided inertial measurement unit, to a pre-selected target point.

TRANSFORMATION OF THE ARMED FORCES

The Department of Defense (DoD) and industry recognize Sandia as a unique provider of systems analyses, engineering prototypes, and validated/verified developmental products.

To mitigate risk in the development of the Army's Future Combat Systems (FCS), a distributed network-centric system-of-systems, Sandia is leading an integrated team of Department of Energy (DOE) and DoD labs to provide objective technical advice to the program office at the Defense Advanced Research Projects Agency (DARPA). The team has used innovative analytical processes to address system-of-systems concepts and provide technical guidance on critical problems including assuring mobility in mined areas, assuring combat identification, and assessing vulnerabilities. We are teaming with Boeing, the lead systems integrator.

Richard Fitak runs tests with the W80 Command Disable System Tester that will be used at the Pantex Plant. Sandia engineers and technicians designed and built the tester.

Sandia's directed-energy group has successfully developed a highly compact high-voltage pulser capable of powering various directed-energy loads. The design uses Sandia's pulsed power experience and combines a battery-driven power supply and Marx generator in producing its output pulse. This development effort has resulted in a battery-driven pulser capable of delivering a 30 gigawatt drive to a load. This extremely compact, lightweight, and rugged approach will enable many future directed-energy systems that require portable high-power drivers.

The DoD has set an ambitious goal of reducing logistics costs by about $20 billion over the next few years. Achieving this goal will require revolutionary new technologies and systems for how we build, supply, maintain, repair, and eventually retire our defense assets.

- Sandia's success in using robotics to refurbish the stealth coatings on the F-117A Nighthawk, saving time and money and improving the final finish quality, has led to additional contracts to develop robotic systems to apply coatings to future U.S. fighter planes, the F-22 Raptor and the Joint Strike Fighter.

Sandia is working with the Air Force and the defense industry to apply a variety of Sandia technology to advanced fighter aircraft including the F-22 Raptor (seen here) and the Joint Strike Fighter.

- The Army's Apache attack helicopter recapitalization program is intended to reduce operating and support costs and improve readiness for the 700-plus units in use. Sandia has applied our reliability models and optimization tools to guide recapitalization investment decisions for a program that had a potential cost of $600 million. Sandia's analyses resulted in a recommendation that the program invest only $150 million in specific subsystems, resulting in a $183 million per year savings for the fleet, while increasing availability. This approach can be applied to many of 26 Army weapon systems undergoing or due for recapitalization, as well as for other complex aircraft such as the new Comanche attack helicopter and the Osprey tilt rotor, vertical take-off aircraft.

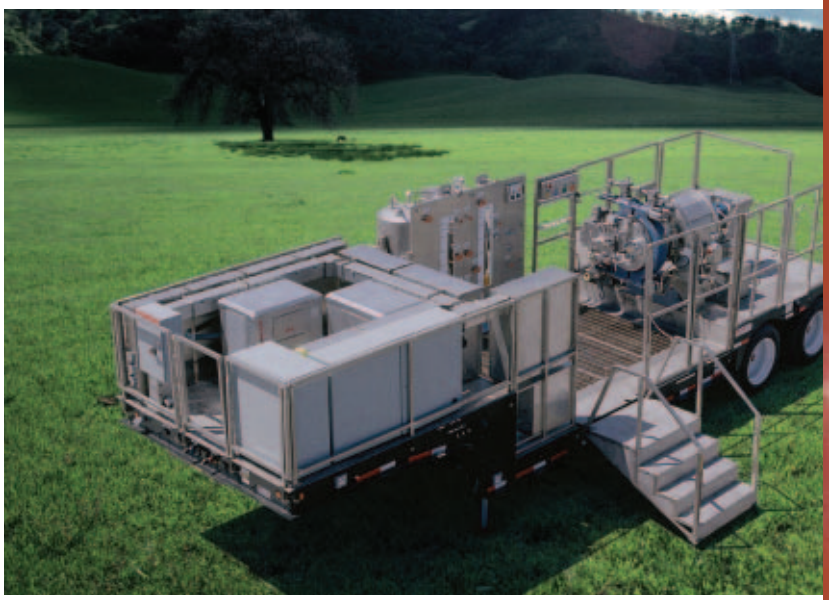
We designed, fabricated, tested, and delivered to the Army our second generation of Explosive Destruction Systems (EDS). These systems use supercritical water oxidation—essentially superheated, superpressurized water—to destroy old chemical warfare munitions that could cause environmental damage if simply detonated. The wastes are destroyed within seconds, producing such commonplace end products as carbon dioxide, water, and salts. The Army now possesses three operational systems ready to destroy munitions throughout the United States. A fourth system can safely contain larger explosives and will now undergo Army tests at the Defense Science and Technology Laboratory in Porton-Down, England.

Much as it has with the Homeland Security Department, Sandia is providing objective advice and assistance to the military's Northern Command, headquartered in Colorado Springs, in areas as diverse as specific technologies and systems organization. The Northern Command's mission is homeland defense.

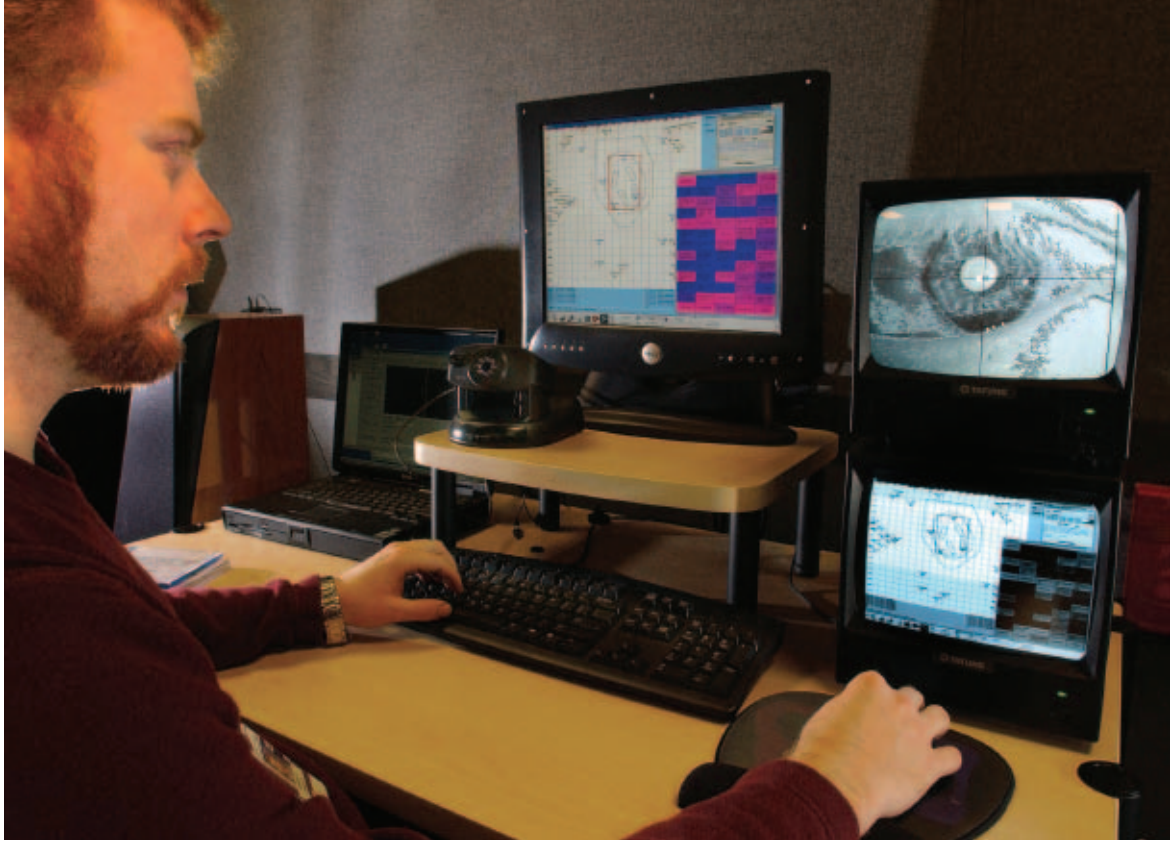
SURVEILLANCE AND RECONNAISSANCE

For more than 15 years, Sandia has been providing solutions to DoD and industry customers for military surveillance and reconnaissance applications. Typical applications include radars, remote sensing, communications, weapons fuzing and firing, microelectromechanical systems, high-integrity software, and data processing and exploitation. Many of these applications—for chemical, biological and radiological detection and identification, for example—are described in other sections of this report, but find equal use on the battlefield or for homeland defense.

Sandia's development of synthetic aperture radar (SAR) shows how our strengths are being applied to pressing military needs. SAR is a computed imaging technique, like medical tomography, relying on a "synthetic aperture" created by flying the small antenna above a target area. Sandia first got started on SAR because of a strong radar heritage for weapons systems. Today, Sandia leads the nation in fine-resolution SAR, precision target location, radio frequency tagging, and real-time image processing.



The second generation of Sandia's Explosive Destruction Systems technology has been tested and delivered to the Army.



Software developer Rob Abbott operates a simulation trainer while a cognitive model of the software runs simultaneously. The model can detect when he makes an error and alert him to it. This is part of a Sandia project to develop new smart machines that would change how people interact with computers. It has potential military and national security applications.

SAR was originally seen only as a day/night, all-weather imager. Sandia has made two significant enhancements to the imaging capabilities of SAR—coherent change detection and interferometric terrain mapping—that demonstrate SAR offers much more than just imagery—information that could not be obtained otherwise.

Coherent change detection (CCD) compares two SAR images taken of the same scene but at different times. CCD can detect physical changes of less than a centimeter on the surface of the target area.

Interferometric Synthetic Aperture Radar (IFSAR) compares images from two SAR antennas separated in elevation to determine the heights of objects in a target area. Through breakthroughs in IFSAR design, Sandia has eliminated the need for the troublesome technique called phase unwrapping, allowing the development of completely automated terrain-mapping systems. An aircraft-based system developed for the Army, known as Rapid Terrain Visualization, can map 30-square-nautical-miles per hour, providing height data every 3 meters and 0.8-meter relative height accuracy—more detailed and accurate than any previous real-time system. These high-accuracy maps are critical for law enforcement agencies, military operations, civil aviation, environmental management, and many other mapping applications.

In high-integrity software, Sandia is developing key technologies and capabilities for the next-generation secure military GPS receivers for the Air Force GPS Joint Program Office. These technologies and capabilities are integrated into the Selective Availability Anti-Spoofing Module, or SAASM, and provide several enhanced functions, including improved anti-spoofing, over-the-air rekeying, encrypted electronic keying, and signal authentication. SAASM, with these enhanced functions, has been mandated by the Joint Chiefs of Staff for all military GPS acquisitions to ensure the security of military GPS capability and the safety of the war fighter who depends on them.

MINIMALLY MANNED WARFARE

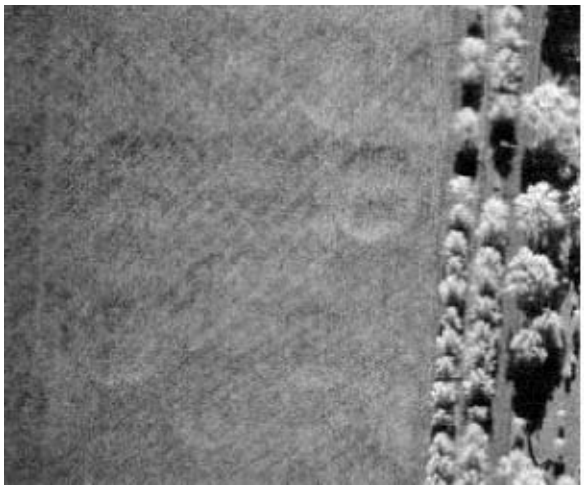
Once futuristic, the success of Sandia's small robotic vehicles on surveillance missions in Afghanistan and Iraq has led to an accelerated program for robotic vehicles for military and other applications. Cooperating squads of robotic vehicles have conducted a variety of military missions and may some day be employed for tasks such as fighting forest

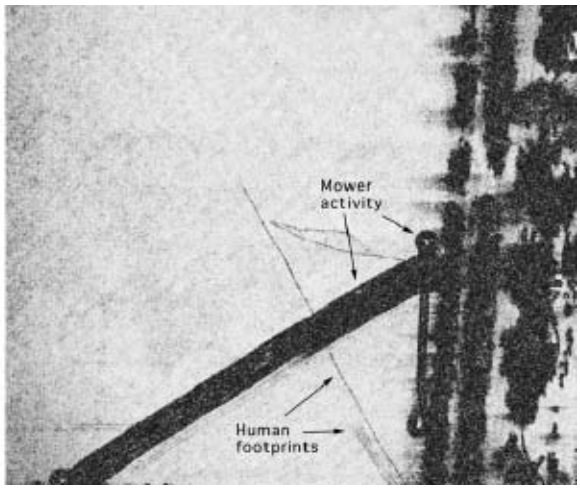
fires, cleaning up oil spills, and delivering and distributing supplies to remote field operations.

Sandia robots range from insect-like (one cubic inch) vehicles equipped with microsensors to large systems for coating aircraft or transferring 20-ton containers between ships at sea. Sandia developed an advanced control system for cranes on Navy ships. This system prevents payload swing while the ship experiences significant motion. Previously, unloading container ships required a tranquil harbor since wave-induced ship motion could produce uncontrollable payload swing. Sandia's control system actively modifies crane motions to prevent the undesirable swing, enabling unloading ships during rougher seas.

As with bomb-disabling systems, Sandia human-centered control systems allow first responders to perform remote inspection and render-safe operations. Tests at the Army's Maneuver Support Center demonstrated that combat engineers and chemical technicians could successfully perform remote operations such as fuse removal, trip-wire cutting, and sample collection using commercially available equipment retrofitted with Sandia software. These tests were done without rehearsal, in the field, and with one hour of training with the equipment. Such operations typically require intensive training for a week or more.

An Intelligent Mobile Land Mine (IMLM) system has been developed to address the needs of the Defense Advanced Research Projects Agency's Self-Healing Minefield Program. The IMLM system adds intelligence and mobility to antitank landmines, allowing them to detect and heal minefield breaches. The units feature a combustion-based hopping mobility system, radio communication and acoustic ranging. Collective behavior algorithms govern unit movement in response to minefield breaches. The ten-unit IMLM system successfully performed breach-healing missions at Fort Leonard Wood, Mo.





A pair of coherent change detection synthetic aperture radar (SAR) images of the same area (a military parade ground) taken 20 minutes apart from an aircraft flying 10,000 ft. above. Sandia's SAR coherent change detection technology compares data from the two passes, and the differences reveal changes and activities that have taken place. Here the image on the right reveals that a mower has passed through the area and a human has walked across it. The technology can be useful for military and civilian applications.

The SnifferStar chemical sensor, described elsewhere in this report (pages 16-17 and 19), is part of a suite of technologies providing the military with capabilities for rapid detection and identification of toxic agents, whether on the battlefield or in response to domestic incidents.

An Intelligent Mobile Land Mine (IMLM) system was developed by Sandia for anti-tank mines, allowing systems to detect and heal minefield breaches.

Homeland Security

PROTECTING *our* NATION *against* TERRORISM

California VP Mim John has primary management responsibility for Sandia's homeland security program, which includes projects throughout the Laboratories.

Since its inception, Sandia National Laboratories has helped the nation solve our most challenging problems. Starting with the physical security of nuclear weapons and the infrastructure that produced, transported and maintained them, Sandia has anticipated a broad spectrum of threats and produced the technologies and systems to protect against them.

Today the technological challenges of protecting our nation against terrorism are as great as any we have faced in the past. In its role as a national security laboratory, Sandia began developing new technologies for the war against terrorism in the mid-1990s. These new technologies, in concert with our comprehensive capabilities to assess the threats to and vulnerabilities of the nation's infrastructures, are now playing an important role in guarding against biological, chemical and radiological threats, as well as providing new capabilities for maintaining the health of infrastructures such as transportation, telecommunications, electrical transmission, water systems, national parks and monuments, and more.

Sandia and other national laboratories are helping to establish the science and technology programs for the Department of Homeland Security, and serving as the wellspring for the integrated solutions that will maintain peace and freedom throughout the world.

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Mim John
Vice President
California Laboratory

A COOPERATIVE RELATIONSHIP FOR NATIONAL SECURITY

About 30 years ago, two events foretold today's uncomfortable national security environment. The massacre of Israeli athletes during the 1972 Munich Olympics was the first worldwide manifestation of modern transnational terror. The 1973 oil embargo was a first indication that our national security depended upon a secure and abundant energy supply. These two events and other emerging threats led Sandia to begin programs that focused on the security of the nation's Nuclear Weapons Complex and our energy production and distribution infrastructure. Sandia became the national security laboratory charged to protect the nation's Nuclear Weapons Complex from any attack or accident and evolved a range of solutions from specific technologies to comprehensive systems vulnerability assessments.

Sandia's Mark Tucker (holding nozzle) demonstrates the Sandia-developed decontamination foam to President George Bush and other federal officials in 2002. The foam is available commercially and is stocked by civilian and military groups who may need to deal with chem/bio attacks.

As the Department of Homeland Security (DHS) began operating in 2003, it faced enormous organizational and system-integration challenges, with more than 200 national agencies drawn under one umbrella, charged with mounting an integrated national response to many ill-defined but potentially catastrophic threats to the nation. Sandia personnel and our longstanding and deep experience with all aspects of national security have been called upon to help meet these challenges.

Sen. Jeff Bingaman (D-N.M.) asks Ruth Boyd a question while visiting Sandia to get briefings and demonstrations of Sandia-developed technologies with homeland security applications.

The DHS and the Department of Energy (DOE) are forging a cooperative relationship in which the DOE labs are providing primary research and development resources for DHS while still carrying out their traditional DOE missions. DOE's three National Nuclear Security Administration (NNSA) labs—Sandia, Los Alamos, and Lawrence Livermore—are taking a lead role in unifying interactions with DHS's technology development programs.

Sandians are helping shape two directorates within DHS. The Information Analysis and Infrastructure Protection Directorate must assess threats to, and vulnerabilities of, the nation in almost real-time across the spectrum of the nation's infrastructures—transportation, telecommunications, electrical transmission, water systems, national parks and monuments, and more. Then the directorate must use that information to decide where to invest the nation's limited resources. That investment can be a mix of guards and guns, cyber security, facilities and capital equipment, or research and development. Sandia's

Duane Lindner talks to the media about an exercise at the San Francisco International Airport. Sandia is working with the airport on a program called PROACT, testing operational capabilities and new detection systems to protect against chemical or biological terrorist threats.

expertise in critical infrastructure analysis and protection, more fully described in our Energy and Critical Infrastructures section, is guiding many of the technical and organizational decisions.

DHS's Science and Technology Directorate originated from a proposal that Sandia helped create that noted the original structure of the department did not take advantage of the nation's science and technology base. This directorate includes chemical, biological, radiological and nuclear defense. Sandia technologies and solutions in these areas—described throughout other sections in this report—have immediate and direct applications for homeland security, and their development and deployment will be accelerated through this directorate.

Many Sandia technical experts worked closely with the DHS during its early months, and several continue doing so. Among other activities, Sandians are defining the department's Biological Defense and Chemical Defense programs, Infrastructure Protection science and technology development programs, and the program to assess vulnerabilities and protect the nation's critical infrastructures. Sandians are also helping structure the information analysis programs in the Information Analysis and Infrastructure Protection Directorate, have helped the chief information officer on information architecture, and are helping establish standards that will guide all of this work.

Sandia will be increasingly involved in work related to homeland security and the war on terrorism. We will also continue our investments involving a wide range of research and development that underpins all our mission-related capabilities. Some examples of recent work include:

Sandia, Los Alamos, and Lawrence Livermore national labs teamed to build a prototype for sustainable urban bio-surveillance and response systems. The prototype is the Bio Defense Initiative Testbed and was supported by the Defense Threat Reduction Agency and DOE's Chemical and Biological National Security Program. We developed the innovative airport surveillance architecture that uses wireless intelligent modules, early warning detectors, and aerosol bio-detectors; led the task to unify the independent systems and local infrastructure; incorporated the Rapid Syndrome Validation Project (RSVP); and conducted advanced architecture studies. RSVP is an advanced system for identifying and quickly reporting disease outbreaks. A follow-on program under DHS sponsorship is being planned.

Sandia has developed techniques and systems to identify, characterize, and potentially disrupt bombs from a distance in a wide variety of situations, up to truckload explosive devices. Sandia's bomb-disabling systems, such as the PAN Disrupter™, are used to disable explosive devices by defeating the physics of an explosion. Sandia bomb disposal robotics technology was licensed to Remotec, thus providing a widespread commercial source. Now bomb squads have a host of new tools—and extensive training to handle bombs in new ways.

The Sandia Modular Architecture for Robotics and Teleoperation (SMART) mimics human manipulation—taking the strain off operators so they can make coordinated motions rather than twiddling a set of controls. It permits operators to perform complicated tasks, such as reaching through a car window to grab a suitcase, with hours rather than weeks of training.

At the request of DOE, Sandia continues work with the United States Postal Service, the Office of Science and Technology Policy, and other federal agencies to develop an efficient and effective response to biological terrorism perpetrated

Sandia has taken a major leadership role in training civilian law-enforcement personnel in antiterrorism methods and technology. The participants seen here were among several hundred who attended a fall 2002 conference near Albuquerque.

Sandia is studying various technologies for quickly detecting anthrax and other biological and chemical agents. Curtis Mowry is seen here testing a prototype anthrax detector.

through the mail, as occurred with anthrax letters sent several years ago to Congress and national news agencies. Irradiation sanitization facilities for both immediate and long-term threats have been established across the nation. Sandia's work includes consultation to the federal agencies and industry, laboratory experiments and evaluations, radiation simulations, and continued system evaluations for the Postal Service.

Other specific technologies—from miniaturized sensors to a system-of-systems approach for early warnings and countermeasures—are discussed throughout this report. These technologies, developed under Sandia's vision of a peaceful and free world through technology, are being brought to bear upon threats much closer to home—our homeland security.

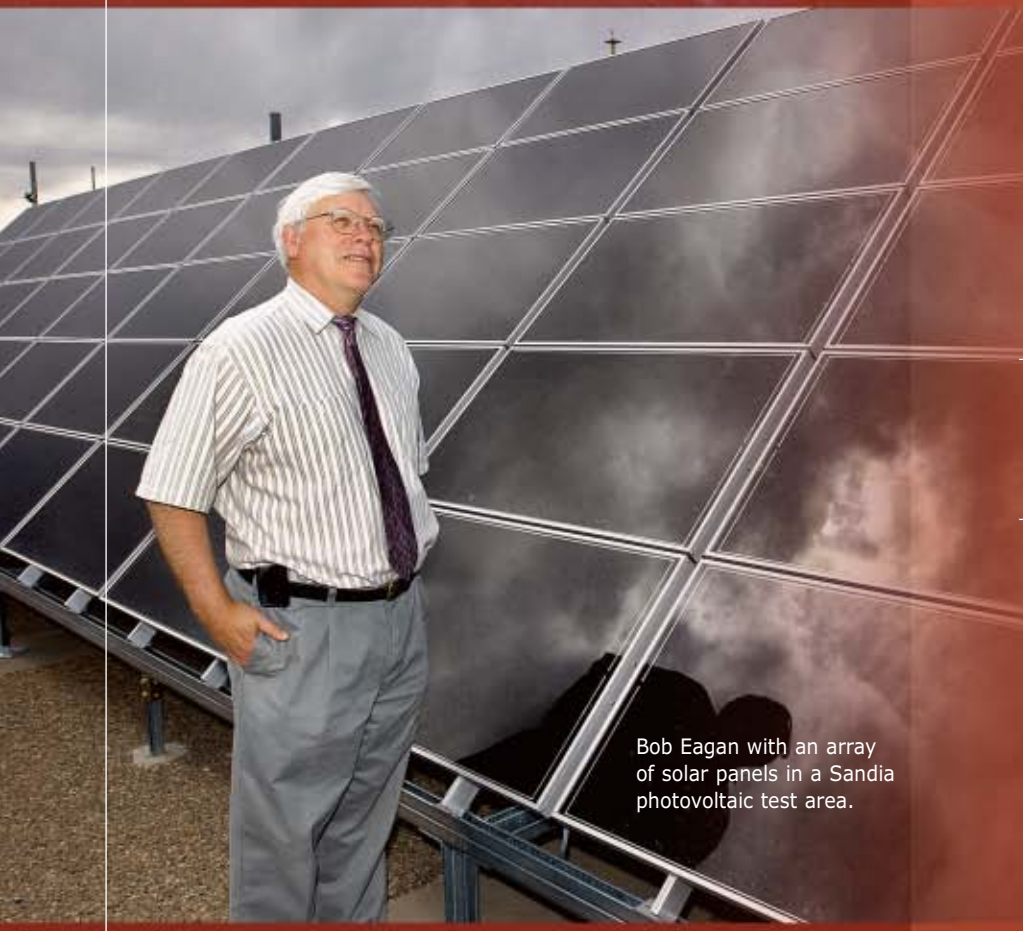
As we look to better serve the nation in the future, we—and our two other NNSA laboratory partners— are focused on establishing an enduring special relationship with the new DHS. We have established strong Tri-lab technical and leadership teams, and we are working together to address both programmatic and organizational needs, such as joint sponsorship, that contribute to cementing the long-term relationship we seek. Within Sandia, we have pulled together our programs for DHS into a formal initiative under Sandia's strategic management unit structure—and we are setting our sights high. Our description best sums it up: "Our contributions will be distinguished by both the systems and tools we provide across the spectrum of threat understanding, vulnerability assessment, and the mitigating and response capabilities that will help make the nation immune to terrorism."

Dawn Kataoka describes a prototype tool for government officials and decision makers to practice responding to a terrorist event. The prototype was produced by Sandia's Weapons of Mass Destruction Decision Analysis Center.

Sandia's handheld MicroChemLab demonstration unit has been used to identify various biotoxins. Its capability is being extended to enable identification of viruses and bacteria.

Energy, Information and Critical Infrastructures

KEEPING RESOURCES *and* INFORMATION FLOWING



Bob Eagan with an array of solar panels in a Sandia photovoltaic test area.

Sandia is also actively working to improve the nation's critical infrastructure surety. We are focusing on infrastructure elements in the areas of transportation, electric power grid, oil and gas distribution, telecommunications, finance and banking, and vital human services.

In addition to Sandia's two main laboratory sites, we have operations in Carlsbad, N.M., Las Vegas, Nev., and small contingents of people in Hanford, Wash., and the north slope of Alaska. The Combustion Research Facility in California is a major, and highly successful DOE collaborative research center.

The Energy, Information and Critical Infrastructure program supports Sandia's core purpose of helping our nation secure a peaceful and free world through technology. Our goal is to enhance the surety (safety, security, and reliability) of energy and other critical infrastructures.

Sandia provides solutions to the complex problems of supplying the nation with clean, abundant, and affordable energy and water. Strides are being made in the areas of energy research, earth sciences, transportation systems, risk management technologies, environmental stewardship, and nuclear waste management.

The men and women who perform the work in this area render exceptional service in the national interest by helping provide clean power for peace and prosperity and helping protect our critical infrastructures.

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Bob Eagan
Vice President
Energy, Information & Infrastructure Surety

A Sandia solar energy team surveys the heliostat field at the lab's National Solar Thermal Test Facility. Sandia is working with Boeing on several cooperative R&D projects, including one to develop the world's largest commercial solar power plant.

CLEAN POWER FOR PEACE AND PROSPERITY

America's national security depends on efficient, reliable energy and an adequate supply of fresh water. Internationally, the relative scarcity of energy and water is a barrier to raising prosperity and defusing conflict. The linkage between energy generation and water use—each generally demands large quantities of the other—is one key to international stability.

The generation and delivery of these resources require a vast interrelated network of circuits, wires and cables, pipelines, information, and services—all part of the nation's critical infrastructures. Sandia develops technologies and expertise to ensure those infrastructures remain secure and reliable.

ENERGY EFFICIENCY AND RENEWABLE/FOSSIL ENERGY

Since the oil embargo of 1973, Sandia has recognized that a secure and abundant energy supply is a national security issue. Sandia is developing technologies to boost production of multiple types of energy, including hydroelectric, geothermal and solar power, and nuclear fission and fusion.

Sandia has for years worked cooperatively with the oil industry to develop more efficient means of producing and extracting fossil fuels, especially with reservoir-management practices as drilling reaches deeper and deeper to tap new gas and oil deposits.

Norm Warpinski (left) and John Lorenz are part of a Sandia team studying how carbon dioxide disperses and where it migrates after it is injected into oil reservoirs to enhance production.

Jim Westmoreland (left) and Ron Jacobsen strap hoses to drill pipe at a Nevada geothermal well to direct polyurethane grout into the well. The special grout shows promise for sealing off critical areas in geothermal wells where high heat and pressures are present.

In partnership with the Department of Energy (DOE), British Petroleum, Chevron-Texaco and the DeepStar offshore drilling consortium, Sandia developed modeling and simulation techniques for better drilling and reservoir management practices. Working with General Electric, Sandia improved the design of hardened drilling bits, resulting in penetration rates three to five times faster than with conventional bits and longer service lives.

Sandia is the science and engineering advisor to the DOE Strategic Petroleum Reservoir (SPR). Over the last two years, SPR has helped ensure oil supplies during the nation's war on terrorism. In response to future demands on SPR, Sandia supplies the geotechnology and engineering needed to fill and update the existing facilities and to lay the foundation for potential future expansion.

At the Combustion Research Laboratory (CRF) in California, we have long studied ways to increase the efficiency and decrease the emissions of combustion sources, especially with diesel engines.

Recent research includes:

- Collaborative experiments of Sandia's Alternate Fuels Optical Engine Laboratory with Lawrence Livermore National Lab have shown that isotope tracing with accelerator mass spectrometry can help us understand how oxygenates affect soot formation in diesel engines. This has led to guarded optimism that particulate and NOx (nitrogen oxides) emissions can be reduced without sacrificing fuel economy.

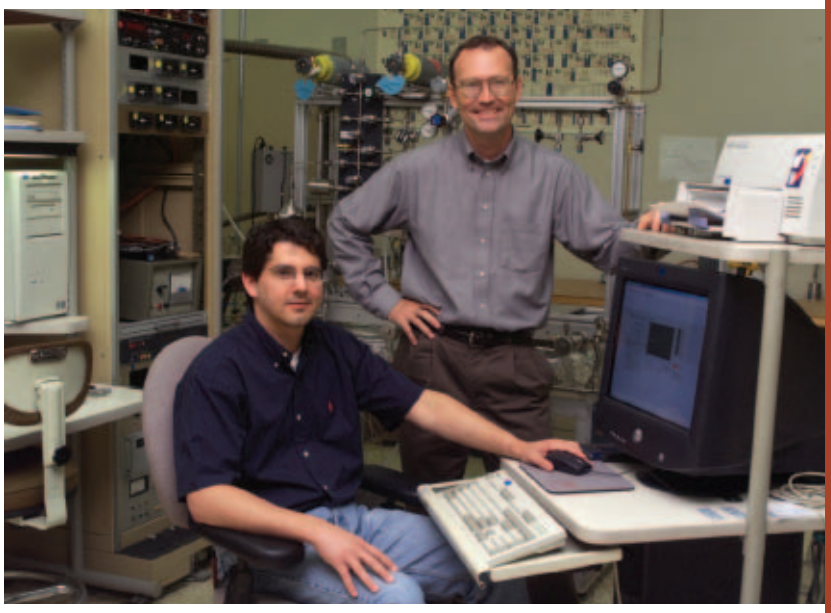
- Scientists at the CRF and the University of Nevada have made the first measurements of the direction in which molecules rotate after a collision. These measurements are of basic scientific importance in understanding how gases heat up, cool down, and come to equilibrium.

- Sandia has worked with The Timken Company to develop a sensor to optimize combustion and energy utilization in electric arc furnaces by the real-time measurement of CO and CO2 concentrations in off-gases. The tunable-laser-based prototype sensor has been successfully tested in field trials and is now installed for long-term tests in Timken's Canton, Ohio, facility.

- In collaboration with Cornell University, the University of Massachusetts, and Lawrence Berkeley National Laboratory (LBNL), the CRF has constructed and demonstrated a new instrument for studying flame chemistry. The ability to detect combustion species without modifying them during the detection is critical. The Advanced Light Source at LBNL provides tunable vacuum ultraviolet (VUV) light that permits us to gently ionize large molecules without fragmentation, enabling mass spectrometric detection. Tuning the VUV light enables unique identification of chemical species by ionization energy as well as mass.

Hydrogen is the clean fuel of the future. The CRF has developed an impressive base of knowledge about hydrogen as a fuel, advancing the nation toward a hydrogen economy so we rely less on foreign energy sources. Sandia scientists, in collaboration with TPL, Inc., and Brady Corp., have developed fuel cell components that have five times the energy density of commercial components. Sandia's breakthrough, funded by DOE's Office of Advanced Automotive Technologies, promises to substantially increase the fuel efficiency of fuel cell and electric hybrid vehicles.

Sandia's California site created the Distributed Energy Technologies Laboratory (DETL) to assist the development and implementation of distributed energy resources. DETL tests microturbine, engine-generator, photovoltaic, fuel cell, and energy-storage technologies both individually and in a collective microgrid. Collaborators include manufacturers, utilities, DOE, DoD, the California Energy Commission, universities, standards organizations, and other national and private laboratories. Energy security is among the benefits that distributed energy resources will offer to the nation's electric power infrastructure. Sandia's Advanced Information and Control Systems Dept. employs DETL in its information security efforts.



Karl Gross (standing) and Eric Majzoub are developing a promising new class of hydrides for hydrogen storage for hydrogen-powered cars.

Richard Simpson of Sandia's Applied Nuclear Technologies department measures a weld in a 1/5-scale-model pressure vessel lower head assembly.

Sandia is working with industry, academia, and government to establish a national research initiative in solid-state lighting—the Next-Generation Lighting Initiative (NGLI). Solid-state lighting uses light emitting diodes (LEDs) that are as much as 10 times more efficient than incandescent and twice as efficient as fluorescent lamp technologies, while offering greater versatility and a longer lifetime. Meeting the goals of the NGLI could reduce the nation's electricity consumption by 10 percent with significant environmental and economic benefits.

A small group led by Sandia accomplished what at least three other large companies could not: demonstrate a commercially viable dish/Stirling system. This solar thermal system is the first to ever demonstrate remote, unattended operation, high availability, low operation-and-maintenance costs, and high efficiency. A number of potential customers, including the Navajo Nation, are interested in the system for remote water pumping and village electrification.

Sandia-developed micro-chemical sensors, called chemiresistors, operate underwater to detect and measure volatile organic compounds.

DOE's Office of Science funds many Sandia energy research projects. Nanotechnologies hold great promise, just as in Sandia's other mission areas, for revolutionary advances. The Office has approved construction of a $75 million Center for Integrated Nanotechnologies jointly operated by Sandia and Los Alamos national laboratories. The project will construct a 90,000-sq.-ft. core facility in Albuquerque and a 30,000-sq.-ft. gateway facility in Los Alamos. State-of-the-art tools and expertise for integrating the world of nanoscale materials and devices with micro and macro technologies will be available to university, industry, and government laboratory researchers.

Sandia's portable gas-leak imager underwent major field tests in early 2003 at a Beaumont, Texas, refinery. Organizers from the American Petroleum Institute called the tests a major success. The imager is a backscatter absorption gas imaging system.

SENSORS FOR THE ENVIRONMENT

A laser-based, gas leak-detection system successfully demonstrated an ability to instantly spot major hydrocarbon leaks in processing pipelines during a field test at a Beaumont, Texas, petroleum refinery. The test also demonstrated the system's capability to observe multiple leaks simultaneously. A typical U.S. refinery spends about $1 million annually looking for these invisible leaks, which contribute to greenhouse gases and smog. The Environmental Protection Agency (EPA) currently requires refineries to conduct comprehensive inspections of their processing pipelines every three months using a handheld "sniffer"—a labor-intensive process that can take weeks to complete.

Seeking ways to streamline the process, the industry, EPA, Department of Energy and American Petroleum Institute have been testing the Sandia-developed technology—called backscatter absorption gas imaging (BAGI)—which uses infrared (IR) laser radiation to illuminate an area as it is viewed by an infrared video camera. If a hydrocarbon gas leak is present, the plumes will absorb the laser light and appear as dark clouds in the video picture. The portable system consists of a shoulder-mounted camera and a backpack-borne power and control unit.

A unique electronic "sniffer" has been developed that can provide real-time in situ monitoring of volatile organic contaminants in air, soil, and water. A small waterproof package houses an array of chemiresistors that can instantaneously detect a large variety of volatile organic compounds. The sensor can be deployed directly in underground wells or water resources, and data are transmitted to a computer for remote monitoring. This system could save millions of dollars at sites that currently rely on traditional manual sampling methods and off-site laboratory analysis.

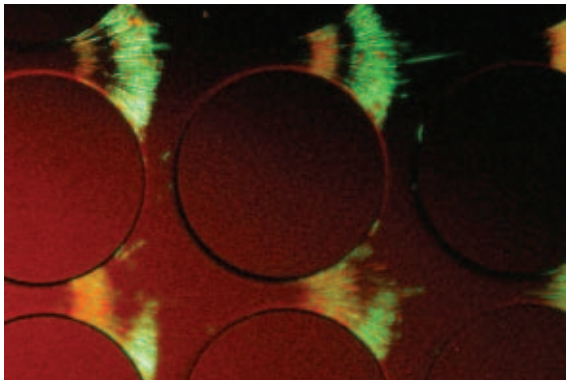
Phil Pohl examines a batch of grain grown hydroponically for cattle feed. This method uses only about one-tenth the amount of water as growing it in an open field.

THE WATER INITIATIVE

The demand for reliable and sustainable fresh water supplies in the United States and internationally is fast outpacing supply. Sandia's water-management initiative seeks solutions to the challenges facing our nation's water infrastructure—challenges of scarcity, systems vulnerability, and the economics of supplying drinkable water. The initiative focuses on monitoring water quality, assessing infrastructure security, providing treatment technologies, and on supporting international cooperative water management.

These areas of concern are addressed through a variety of programs. Sandia, in cooperation with the American Water Works Association Research Foundation and the Environmental Protection Agency (EPA), developed a security risk assessment methodology for assessing the surety of water utilities. This water infrastructure assessment tool has been employed to evaluate security and mitigate risks at several large municipal water utilities.

Complying with the new EPA arsenic drinking water standard of 10 parts per billion could cost affected rural water customers an additional $100 per month, particularly in western states where natural arsenic levels are high. A Sandia technology, specific anion nanoengineered sorbents (SANS), has arsenic-trapping properties that may find application in water purification systems. SANS is simpler, safer, and



Drinking-water monitor: A Sandia research team is trying to develop a monitor using a live-pathogen concentrator. Across a microfabricated array of circular posts, dead and live E. coli bacteria collect into separate bands when a voltage is applied. Live cells are less conductive than dead ones, so are more strongly repelled and appear as outer bands.

The US is dependent on a complex framework of interdependent networks and systems to maintain a continual flow of goods and services. Critical infrastructure surety projects at Sandia work to ensure that these networks and systems keep working consistently and reliably.

more efficient than purification technologies currently on the market. SANS may reduce the cost of municipal and rural communities' compliance with EPA standards and may also be economical enough for use in homes, schools, and apartment complexes served by single wells. SANS systems also can be adapted to rid industrial wastewater and process streams of other contaminants.

Purification of our saline water (more than 97 percent of this planet's water) could provide relief to a growing demand for fresh water that already outstrips supply in many parts of the world. Sandia, in cooperation with the Bureau of Reclamation, has taken a two-pronged approach: 1) A desalination R&D roadmap defining a path through the year 2020 that will support solving our water supply-related needs by advancing water desalination technology; and 2) Design of a research facility in the Tularosa Basin to test and evaluate novel desalination technologies.

Community-based management of water resources is key to using every drop wisely. We have developed a dynamic simulation model of the hydrology, demography, and economy in the Middle Rio Grande Basin to help stakeholders understand the ramifications of trade-off decisions, from installing low-flow toilets to providing water for endangered species. Our cooperative modeling process bridges the technical demands and capabilities of a rigorous, quantitative model and the collaborative social processes required for community-based management. This process is already contributing to water sustainability in some areas.

CRITICAL INFRASTRUCTURE PROTECTION

The National Infrastructure Simulation and Analysis Center (NISAC) has become a key element in the national effort to protect critical infrastructures such as electrical power grids, natural gas and oil systems, telecommunications, etc. NISAC, a Sandia-Los Alamos partnership, was congressionally chartered and is being incorporated into the Department of Homeland Security. NISAC is developing models and simulations of critical infrastructures, their interdependencies, and the downstream consequences of attacks to identify and resolve critical vulnerabilities.

Before and following the 9/11 terrorist attacks, Sandia conducted wide-ranging risk assessments on behalf of many national agencies. Sandia security experts have traveled the country developing and applying security assessment methodologies and other risk-management tools for the nation's dams and power systems, government buildings, chemical plants, water supplies, and other potential targets:

- We assessed management systems and security practices of the U.S. Bureau of Reclamation, the nation's second largest producer of hydroelectric power. The analysis led to the integration of the latest supervisory-control and data-acquisition technologies at six hydroelectric projects, including Hoover, Shasta, and Grand Coulee dams. The program is now in its second phase, providing similar input for five additional dam sites. About

10 percent of America's electricity needs are provided by hydroelectric power.

- A classified assessment of nuclear power plant vulnerability was conducted in less than four months. The multilab team was engaged by the Nuclear Regulatory Commission to carry out innovative analyses to better understand the consequences of specific terrorist threats on nuclear plants. Two ongoing, plant-specific vulnerability assessments are refining insights gained in the initial study.

- For years Sandia has lent its systems analysis abilities to the national power grid. Labs' researchers in New Mexico and California study the security of communications between control systems, the distribution of power generating facilities and how it could be improved, and system vulnerabilities. Potential attacks on the system have long been recognized to have implications to the economy and national security.

- On request, Sandia assessed the impact of such a threat on numerous NNSA, DoD and NRC facilities. The assessment team was responsible for developing the methodology to quantify the structural response and consequence of any fires that might ensue. This endeavor brought to bear unique technical expertise, state-of-the-art computational tools, and a unique experimental infrastructure to address a problem of national importance.

The Information Operations Red Team and Assessments (IORTA) program performed numerous cyber system assessments, evaluations, and vulnerability experiments for a broad range of prototype-through-operational systems. Customers include civilian government agencies, the DoD, industry, and critical infrastructure assets including electricity, communications, water, oil and gas. Sandia researchers are developing information security practices to meet the next generation of Internet security threats. The research team developed Standard Agent Architecture II/Agent-in-a-box, which has brought revolutionary advances in agent and information security. The Advanced Information System Lab's (AISL) intelligent agents provide a dynamic defense for domains, a significant contribution to national security that also represents substantial commercial value for the multibillion-dollar cybersecurity industry.

Workers add rhodium foils between uranium pellets in Sandia experiments to determine the extent to which rhodium reduces the reactivity of the uranium.

Standards and controls are vital to the predictable and secure flow of electrical power. Our programs include technologies for automatically diverting or shutting down electricity flow from grid-connected systems when an electric distribution line shuts down—an important breakthrough that encourages distributed energy systems development.

THE GLOBAL NUCLEAR FUTURE

As the nation comes to grips with the energy challenges of the 21st century, political and public support for nuclear power will be vital if it is to remain a major contributor to our energy future. Interest in the U.S. for new nuclear power plants is growing. The Global Nuclear Future is a Sandia vision, now shared by many others, about how

Sandia's annular core research reactor (ACRR) has been upgraded and is being used in various weapons and energy testing programs. Here, Ron Farmer makes some last-minute checks before a test.

nuclear energy, bolstered by appropriate public policy decisions, can serve the nation's requirements for domestic energy security, global national security, nonproliferation, and nuclear materials management. The vision incorporates advanced reactors with greater efficiency, and vastly reduced waste and risk of producing weapons-usable materials. Part of the output of these reactors will be hydrogen, the clean fuel of the future. As the most abundant element in the universe, separating hydrogen from water is energy intensive, but a perfect task for reactors.

Through all the years that nuclear power has been on the wane in the U.S., Sandia has continued to maintain substantial capabilities in nuclear power-related issues and is uniquely poised to consider nuclear power as a broadly integrated international system.

Russia's Kurchatov Institute President Evgeny Velikhov visited Sandia, where he was briefed on a variety of nuclear-related technologies, including the transformation of excess weapons grade materials. Cooperation between Sandia and Kurchatov led to a formal agreement between Presidents Bush and Putin at the Moscow Summit Conference to identify areas of collaboration on advanced nuclear fuel cycle research and development.

Sandia's Telemetry Technology Team demonstrated a wireless instrumentation system, which couples power and data, allowing instrumentation of sealed containment vessels for nuclear materials. The power and data are coupled through the container walls via magnetic coupling between concentric coils inside and outside the canister. This technology supports the goal of ensuring safe transportation of nuclear materials and elimination of the costly individual container inspections. Bench testing has demonstrated the feasibility of transferring energy and data through multiple walls of stainless steel and lead. Future development will require high temperature electronics to measure hydrogen content, pressure and temperature, and add electronic identification to each containment vessel.

WASTE LEGACY

To create the nation's first high-level waste and spent nuclear fuel geologic repository, the Nuclear Waste Policy Act requires a site recommendation from the Energy Secretary, with congressional concurrence and presidential approval. The Secretary's site recommendation of Yucca Mountain could not have gone forward without Sandia's technical contribution to the site characterization and performance assessment. Sandia directly contributed to a monumental body of work with defensible analyses of site performance, for a decision of national importance affecting America's national and energy security.

Because of recent design changes to the repository for Yucca Mountain, a large portion of the underground storage area was moved into a rock unit that previously had not been explored and was found to contain numerous large voids. Mechanical data for this rock unit were urgently needed for the design to proceed, presenting a significant testing challenge. We developed a unique approach to the

An engineer checks out a tunnel (drift) at the proposed Yucca Mountain nuclear waste repository. Sandia researchers are helping understand the mechanics of rock structure there.

problem, including a field test that mechanically stressed a large tendon of rock between two slots cut in the wall of the tunnel.

Scientists in Sandia's environmental management science program discovered a family of tunnel-collapsing materials that is capable of trapping a variety of molecules, including the radioactive isotope strontium-90. Called Sandia octahedral molecular sieves (SOMS), the materials contain micropores that clean up industrial processes and waste streams, filter out valuable chemicals for reuse, and trap radioactive residues, such as strontium-90, that accumulate inside underground storage tanks used in nuclear weapon production. In tests, the SOMS trapped 99.8 percent of strontium-90 ions from solutions containing chemically similar and highly abundant sodium ions. Because the SOMS are crystalline and inorganic, they stand up to the highly caustic environments found in the tanks. Furthermore, when heated to about 500°C, the strontium-saturated SOMS collapse into a dense, glass-like material that locks the strontium tightly into an impervious crystalline structure.

Gary Harms uses a new Sandia-built reactor to conduct experiments that could pave the way toward possible changes in nuclear-waste transport and storage regulations.

Strengthening Our Communities

GIVING BACK *through* SERVICE

Joan Woodard reads to students at the Sandia Base Elementary School during the 2003 "Read Across America Day."

We at Sandia take pride in being part of our communities. We cherish the beautiful areas in which we live and the wonderful people, our neighbors and friends. The people of Sandia National Laboratories have a long tradition of service in their communities. Since 1993, with support and encouragement from Lockheed Martin Corporation, our service and partnerships in the community have increased dramatically. We benefit tremendously from our partners and friends in our communities, and we proudly give back through our commitment and service. The following pages give representative samples of this; many more examples could be cited.

★ ★ ★

Joan Woodard
Executive Vice President and Deputy Director

Since 1993, when Lockheed Martin Corporation became our operating contractor, we have made a concerted effort to partner within the communities where we live and work. This has meant a greater participation by Sandia employees serving on community boards, chambers of commerce, service clubs, and museum foundations; we also have expanded the grassroots participation of our staff in volunteer efforts for community charities. Lockheed Martin donated more than $1 million last year to local cultural, educational, and human services groups, bringing the total to more than $14 million.

Hispano Chamber of Commerce, which named Sandia as the Corporate Partner of the Decade.

Regionally, Sandia as a corporation is involved in its communities through the development of growth strategies, workforce and transportation issues, leadership programs, and state business and economics. Sandia provides major economic benefits locally, regionally, and nationally through the approximately 8,000 people who make up our workforce, which generates a payroll of more than $700 million in direct salaries and contract labor. In 2002, Sandia's

Sandia/California employees inquire during the annual Livermore Employee Assistance Program (LEAP) fair about how community agencies use contributions to provide services.

Sandia's longstanding contributions to the Albuquerque area, the state and the nation have been recognized by community organizations such as the Presbyterian Healthcare Foundation, which presented Sandia/Lockheed Martin with its prestigious Award of Excellence, and the

expenditures totaled more than $2 billion. We placed contracts with the private sector for $900 million in goods and services, including $365 million in contracts with New Mexico businesses and $89 million with California businesses.

Happy face and feet — More than 450 youngsters in the Albuquerque area received new shoes in 2003 from Sandia employee and retiree contributions to the annual Shoes for Kids drive.

Employees are encouraged to volunteer their time to a variety of organizations and causes, and they respond enthusiastically by becoming role models and partners in community programs and contributing to youth education. The following are a few of the ways Sandians made a difference in their communities over the past year.

- Sandians at Livermore and Albuquerque have now attained three straight years of donating more than $2 million to local United Way and other charitable agencies, with New Mexico employees alone exceeding $2 million for the first time. Sandians in California, through the Livermore Employee Assistance Program, donated nearly $230,000 to charitable organizations. This annual Livermore charity drive has raised more than $3.8 million since 1969.

- The fundraising program was supported by Lockheed Martin Corporation, which continued its tradition of making major philanthropic contributions to the Middle Rio Grande community, particularly in support of educational programs for youth.

- One of Sandia's oldest traditions of community giving, our Shoes for Kids program, raised $16,000, a new record, and provided shoes for 450 children from Albuquerque-area elementary schools last year. Shoes for Kids is funded by employee and retiree donations and has been helping needy children since 1959.

- In California "holiday spirit" drives each year, employees donate about 2,000 pounds of food and some 750 gifts for homeless shelters, children's clubs, and developmentally disabled recipients in San Joaquin and Alameda counties.

- Sandia and Lockheed Martin Corporation recognized 32 graduating high school students who excelled in school and community activities after overcoming adversities such as illness or addictions, surviving the deaths of parents, becoming teen parents, or living on their own. The annual Thunderbird Awards for exceptional achievement include a grant.

- In line with our focus to support non-profit organizations that help the Middle Rio Grande community grow and prosper and specifically to encourage the development of youth, some of the projects that Sandia volunteers completed

were: Landscaped the front of La Luz Elementary School; repaired the ceiling and painted three classrooms at Cuidando Los Ninos; helped with Reading Rally 2002 at Dolores Gonzales Elementary school; and spoke to many high school students about staying in school. We also had three drives for books, school supplies, and food to benefit needy school children.

- Funded by a $40,000 grant from Lockheed Martin, Sandians built their third Habitat for Humanity House, and employees donated $1,000 to the new owners for home accessories.

- In concert with Lockheed Martin, the Albuquerque Hispano Chamber, and the National Hispanic Cultural Center, we've partnered on a very successful Summer Science Camp, bringing the excitement of science to more than 440 kids last year alone, and nearly 1,000 kids over the last four years.

YOUTH EDUCATION

Our commitment to education focuses on educational outreach programs that help set the stage for scholastic success. Sandians support these goals by judging science fairs, speaking at career events, helping to teach in the classroom, and serving as mentors and tutors.

- Sandia's Environmental Education Program provides students and teachers with hands-on activities that demonstrate the need to protect our natural resources. Sandians made presentations at a number of New Mexico events, including the fourth annual Youth Conference on the Environment, the Women in Science and Engineering Conference, and at the University of New Mexico's Valencia Campus Technology Fair.

- Sandia continued its longstanding support of a New Mexico state initiative, Strengthening

Ken Kuzio (left) and Chuck Townsend help during "Make a Difference Day" with a fall gardening project to plant bulbs for the enjoyment of assisted care residents at an Albuquerque senior center.

Quality in Schools, which provides expertise needed to develop a world-class education system in New Mexico.

- Through monies provided by Lockheed Martin, Sandia provided professional development opportunities to approximately 400 local science teachers.

- Sandia's CroSSlinks program increased to 80 the number of Sandia volunteers serving as technical role models in 70 local elementary schools.

- The National Atomic Museum launched the Up'n'Atom mobile Science and Math Outreach program, designed to bring information about science and technology into many of New Mexico's small towns and pueblos. Nearly 20,000 schoolchildren participated in the

Darline Polonis of the National Atomic Museum and students examine a poster during Space Day 2003. Sandia, Lockheed Martin, and the museum team up to support Space Day activities each year.

Everyone seems to have the answer to a question posed by Sandia volunteer Thomas Davis as he helped prepare an Eldorado High School team for a 2003 Science Bowl competition.

Many Sandia retirees stay active in community affairs. Here, Karen Robinson (right) explains how night vision works to a Collet Park Elementary student. Karen coordinates the school's science fair and other science programs.

museum's educational programs over the past year, including the successful ZOOM into Engineering Day.

- Volunteers and corporate contributions enable many community events near our California site, including the annual Math & Science Awards Banquet for area high school girls, their parents, and teachers, and spring and fall Expanding Your Horizons in Science and Mathematics conferences for about 600 young women in San Ramon and Stockton.

- California employee volunteers also support two regional high school Science Bowl academic competitions in Northern California. Finalists compete nationally in Washington, D.C., where they have placed in the top three teams two years in a row. In New Mexico, Sandia coordinated and provided volunteers to support regional middle and high school Science Bowls.

- More than 2,700 eighth and ninth graders attended the fourth annual School to World career day, an opportunity to talk with people in the working world about job opportunities and the relationship between schoolwork and work skills. Sandia and New Mexico businesses, schools, and government agencies sponsored the event. Sixty-five of the more than 550 volunteers were Sandians.

- In 2002, Sandia internships brought 700 students to Albuquerque and more than 200 to Livermore for mentoring and immersion in our culture and work. Half of these students were interns in our summer employment program. An additional 12 interns in Albuquerque were drawn from graduates of our Advanced Manufacturing Academy, which gives students at Albuquerque high schools information about employment in technical fields. The academy's elective four-year curriculum stresses math,

Bad hair day? This young lady got a real charge out of her experience at a "Fun in the Sun Science Day." Sandia's community involvement department sponsored several such events at community centers in the summer of 2003.

physics, chemistry, computer applications and computer-aided design, machining and materials processing skills, and automotive and transportation technologies.

- Our Hands-On/Minds-On programs instruct about 400 middle and high school students each year in robotics and bridges, math and money, web page design, health and medicine. The programs are designed to give Native American, African American, and Hispanic students hands-on science and engineering experiences.

- To encourage summer learning, Sandia launched the Fun in the Sun Summer Science program providing hands-on science activities at 13 community centers.

CHALLENGING ISSUES

Sandia helps numerous New Mexico businesses and civic organizations address community needs such as water and air quality, arid land issues, safety, and security. One example is the work that Sandia did through its New Mexico Small Business Assistance Program to demonstrate to an Estancia, N.M., greenhouse owner that animal feed grain can be grown hydroponically in the greenhouse using about one-tenth the amount of water that it takes to grow the same feed in an irrigated open field. The hydroponic technique grows the grain in water containing dissolved inorganic nutrients rather than in soil. This particular demonstration project has far-reaching potential for dramatically reducing water usage in high-desert and other arid regions because the bulk of water used in many of these areas is for the production of livestock forage.

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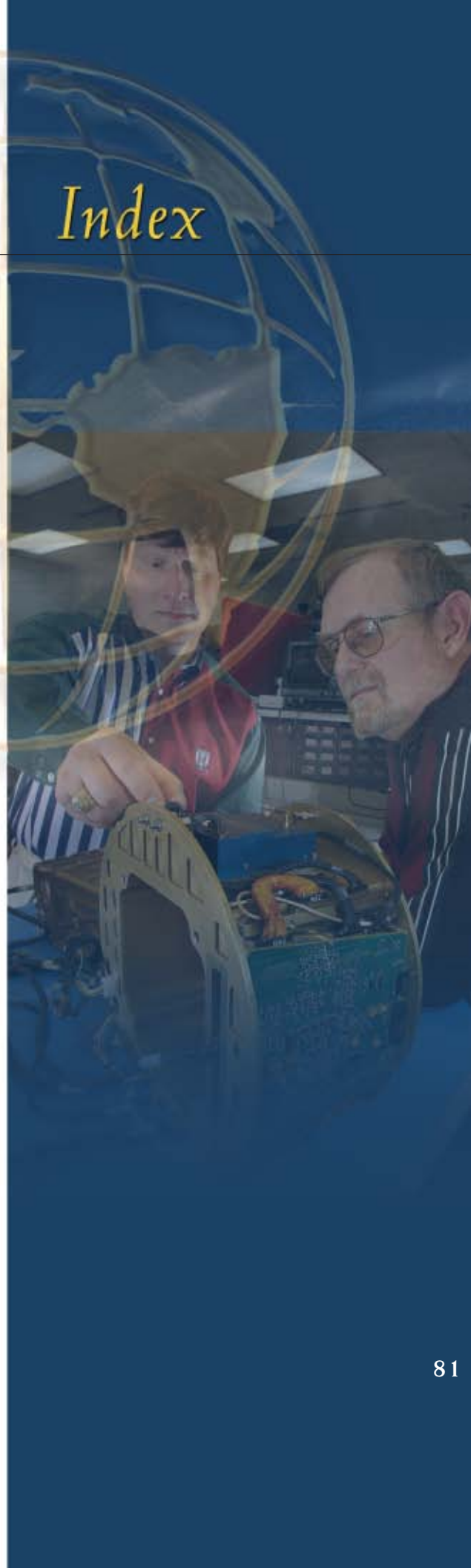

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annual report 2003-2004

Sandia National Laboratories

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National Nuclear Security Administration

LOCKHEED MARTIN

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