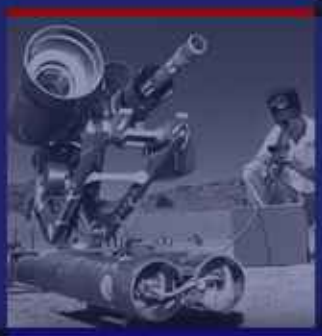


SANDIA NATIONAL LABORATORIES
ANNUAL REPORT 2002/2003

Helping Our Nation Secure a Peaceful and Free World Through Technology

Sandia National Laboratories

A Department of Energy National Laboratory

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 research and development.

The Lockheed Martin Corp. has managed Sandia since Oct. 1, 1993, for the U.S. Department of Energy. 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, Office 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 7,900 people and has two primary facilities, a large laboratory and headquarters in Albuquerque and a smaller laboratory in Livermore, Calif.

Overview

Sandia National Laboratories

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

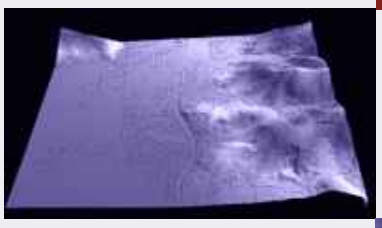
We develop technologies to maintain our nuclear deterrence; sustain and modernize our nuclear arsenal; prevent the spread of weapons of mass destruction; protect our national infrastructures; defend our nation against threats such as terrorism; provide new capabilities to our armed forces; and ensure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

As one of the nation's national security laboratories, 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.

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 deployed across the nation and around the globe.

Although Sandians are proud to respond to national security needs, our forward-thinking and creative employees do much more than just respond to needs as they develop. Many of our people are charged with "thinking in the future tense" — about new types of national security threats that may develop five years, ten years, and more down the road. We then work to develop solutions before those threats become reality. That's truly what we're all about and what makes our work so vital to the nation and the free world.

These proud employees are featured on a poster illustrating Sandia's strong commitment to the concept of "one team delivering the whole job." They represent many of the laboratory's business units. They are (from left) Michael McDonald, Tina Nenoff, Cliff Ho, Larry Yellowhorse, B. J. Jones, Grant Aguirre, and David Rogers.



"Helping our nation secure a peaceful and free world through technology."

Table of Contents

Sandia National Laboratories
Annual Report 2002/2003

4 **Helping Protect America**
during a time of conflict

6 **Science & Technology**
Pursuing science with the mission in mind

18 **Nuclear Weapons**
Preserving national security

26 **Nonproliferation & Materials Control**
Making the world a safer place

36 **Countering Emerging Threats**
through technological superiority

44 **Energy & Critical Infrastructures**
Maintaining supplies and systems

54 **Technology Partnerships**
for mission success

62 **Community Involvement**
Giving back through service

Helping Protect America
during a time of conflict

Today we are operating at an unprecedented intensity to develop and deploy national security technologies.

Sandia's core purpose is "Helping Our Nation Secure a Peaceful and Free World Through Technology." Like all Americans, Sandians were shocked and angered by the tragic events of September 11. We immediately rallied to provide our help—both to prevent such acts of terrorism in the future and to support the troops moving into Afghanistan. We have not let up.

After Sept. 11, the nation did turn to Sandia for many technologies and systems to better protect our citizens and troops and to help win the war against terrorism. Sandia's staff rapidly shifted gears to turn up the rate of progress in our national security work, suddenly rendered even more important by the instantaneous change in the free world's security situation.

Sandia is doing its utmost to develop science and engineering solutions to national security problems.

All across the Labs, individuals and teams made heroic efforts to extend our technology contributions. Many of these projects began five or more years ago, when we began to focus on additional kinds of threats to a peaceful and free world. Today we are operating at an unprecedented intensity to develop and deploy national security technologies.

We are one of the nation's foremost technical institutions, fulfilling missions for the National Nuclear Security Administration, the Department of Energy, the Department of Defense, the Office of Homeland Security, and other federal agencies. While Sandia's primary mission is to maintain the nation's nuclear deterrence capability, we also work in a variety of ways to reduce the vulnerability of the United States to proliferation, threat, or the use of weapons of mass destruction.

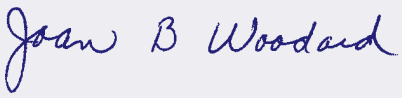
Sandia is doing its utmost to develop science and engineering solutions to national security problems. We do that with many of the best intellectual, scientific, and technical minds this nation has to offer. We are now well into a five-year program to hire 2,500 new scientists, engineers, technologists and administrative staff—nearly a third of our current workforce. 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.

For all Sandians, whether veteran employees or just starting out, the challenge is nothing less than to predict the future and develop technologies to counter future threats to national security.

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 *http://www.sandia.gov.*

C. Paul Robinson
President and
Laboratories Director



Joan B. Woodard
Executive Vice President and
Deputy Director

Science & Technology

Pursuing science with the mission in mind

Sandia's missions require extraordinarily strong science and technology. We strive for and achieve advances that greatly improve performance—often by factors of ten, a hundred, or even a thousand. We have achieved many advances in our nanotechnologies, microsensors, pulsed power, and advanced materials programs in the past few years. Our research on light-emitting diodes could eventually increase the electrical efficiency of lighting by a factor of ten. Our new modeling techniques for nanotube-based transistors could eventually build computers with logic devices more than one hundred times smaller than today's tiniest silicon devices, with each device two or three times more functional.

While spurred by the demands of national security, these advances and others are steps on the way to achieving a peaceful and free world through technology. The long-term benefits of greatly increased electrical efficiency, for example, are the conservation of energy resources and a lesser environmental impact. A great deal of the nation's progress has resulted from an exceptional ability to conduct science with the mission in mind—to discover and engineer raw technology into revolutionary products.

Building upon our traditional strengths in materials and computational sciences, we are making significant advances in micro- and nanotechnologies, information technologies, and biotechnologies. These three technologies will drive the Next Generation Economy.

Al Romig
Vice President
Science & Technology and Partnerships

Sandia researcher Mark Tucker (holding nozzle) demonstrates the Sandia-developed decontamination foam to President George Bush (center) at a July 2002 display of DOE labs' antiterrorism projects at Argonne National Laboratory. Other officials seen here are (from left) Ray Orbach, DOE's Office of Science, DOE Secretary Spencer Abraham, and US House Speaker Dennis Hastert (R-Ill.).

Sandians Doug Chinn, Craig Henderson, and Michael Winter display a chrome mask for LIGA, a three-stage production process for fabricating microscopic parts. (Courtesy of East Bay [Calif.] Business Times)

Microsystems Promise Macro-benefits

Rapid detection, identification, and destruction of toxins are key technologies that Sandia has been developing for many years. Our efforts range from development of unique, nontoxic decontamination foams and mists to the borders of science: microsensors and handheld detectors for chemical and biological toxins.

Sandia demonstrated the potential of microsystems for national security by deploying mobile robots, each less than one cubic inch in volume and equipped with microsensors and communications, across a test range as a chemical agent simulant was released. The microbots not only detected the simulant but also measured its concentrations and thus tracked how the plume spread and dispersed.

We are placing the equivalent of fully staffed laboratories in the hands of first responders. This year our MicroChem Lab became the MicroChem/Bio Lab on a Chip. It now performs rapid chemical detection as well as detection and identification of important biotoxins, such as staph, ricin, and botulism.

It uses sensors, microsystems, and nanotechnologies developed at Sandia, where microfluidic physics and chemistry are research strengths. It uses nanotubes and micromachines that can grab single blood cells without harming them. Its heating elements vaporize minute quantities of compounds that are analyzed by tiny sensors.

Sandia's fabrication facilities are extensive. They can be used to design complicated flow channels with electrodes embedded in the glass, and fabricate them. They can pattern porous polymers and arrays of posts within channels. Sandia maintains a full-flow CMOS (complementary metal-oxide semiconductor) fabrication facility. And Sandia employs the most up-to-date technologies in processes such as deep reactive-ion etching, embossing, casting, micro-injection molding, and LIGA—a German acronym for lithography, electroplating and molding. Surface properties of materials can be defined and tailored using plasma oxidation. Sandia is exploring the use of silicon-based microfluidic systems, fabricated using CMOS-compatible processes and equipment, for high-voltage electrophoresis and other applications.

LIGA metallic and polymeric microstructures have been prototyped for first use as critical components flight-testing in 2003. This flight test will be a first critical step toward using this microsystem technology in weapon systems.

Sandia researchers also designed a wireless, battery-free sensor that would power itself by converting mechanical energy from the subtle vibrations of buildings and bridges into electrical power. The sensor uses this vibration power to take measurements, then stores the data in a memory device that

Julie Last uses an atomic force microscope to image the travels of receptor-lipids on an artificial cell membrane. Sandia researchers have witnessed molecular movements that could evolve into some of the first useful tools for nanoconstruction.

can be read from outside the structure—through concrete, steel, and other building materials—with a commercial radiofrequency (RF) tag reader used by trucking and warehousing operations to track tagged inventories.

Civil engineers might use such a device to check the health of a structure—a hospital, government building, dam, or tunnel—following an earthquake, storm, bomb blast, or other catastrophe. Because the sensor system requires no hookups to batteries or wires, it could be embedded into a structure during construction and ignored until a need arises to take a reading.

Sandia also developed very sensitive hand-held radiation detectors using a unique semiconductor. This technology replaces large, refrigerated units, and could become essential for detecting clandestine nuclear materials.

Nanotechnologies—
New Materials, New Devices, New Potentials

Nanotechnologies operate at sizes approximately a thousand times smaller than microtechnologies. Nanotechnologies are of interest not only because they can be used to make very small structures, but also because the commonly understood properties of ordinary materials are dramatically different at the nanoscale. These differences provide intriguing possibilities for those who can integrate these new capabilities into the micro- or even macroworld.

Silicon, for example, in nanosized clumps emits light, offering a new realm of operation for a mainstay semiconductor material widely known for controlling electrons but not photons. The fluidity and friction of apparently well-characterized materials change unpredictably at the nanoscale. For example, gold and copper become as hard as ceramics.

Nanotechnologies at Sandia will be developed at a new facility, the Center for Integrated Nanotechnologies, or CINT, in a joint program with Los Alamos National Laboratory. CINT will have four areas of expertise: using nanoscale structures to manipulate electrons and photons:; designing and synthesizing complex, self-assembling nanostructures; exploring the mechanics of behavior at the nanoscale; and importing biological principles 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.

Labs researchers recently created and then examined molecular movements that could evolve into some of the first useful tools at future nanoconstruction sites, where proteins might be shuttled from place to place in tiny chemical wheelbarrows or built upon molecular scaffolding. Using improved observational methods, the Sandia team watched huddled molecules on a man-made cell membrane rapidly disperse across the membrane when they latched onto free-floating ligands (chemical attractors), then rehuddled when the ligands were removed. The behavior mimics biological reactions at the cell level, such as immune system response to viral particles. The work is based on previous research at Sandia to create metal-detecting sensors using chemical recognition events.

A collaboration between Sandia and IBM modeled nanotube transistors with gates 100 times smaller (just 10 nanometers) than today's tiniest silicon gates. The partners modeled a device in which the electrodes of the gates were linked by a strong, thin filament of graphite-like carbon, rolled into a nanotube no more than two nanometers (about 10 atoms) in diameter.

Conventional devices can be switched off by raising the voltage at a gate between two electrodes. The new model revealed that increasing voltage at the gate first turns off the transistor as in a conventional device, then switches it back on. This surprising result is due to quantum mechanical effects that are manifested only at the nanoscale.

Increasing Lighting Efficiency by Ten Times

Sandia is at the forefront of a revolution that promises to change the way we light our homes, offices, and world. Sandia researchers are working to establish the fundamental science and technology to replace the country's primary lighting sources, incandescent bulbs and fluorescent tubes, with semiconductor light-emitting diodes (LEDs)—solid state lighting.

LEDs are already found in toys, electronics, traffic lights, automobile signals, and large outdoor displays—devices that require durability, compactness,

Top photo: Close-up view of LED's substrate.

Art Fischer holds a sapphire substrate with indium gallium nitride layers. This is the base material for one type of semiconductor light-emitting diodes (LEDs). LEDs may one day replace incandescent bulbs and fluorescent tubes, substantially reducing electricity usage.

Researchers examine a part of Sandia's Z-Beamlet facility, the world's third largest pulsed laser, used to image the effect on a target of a firing of Sandia's mighty Z machine.

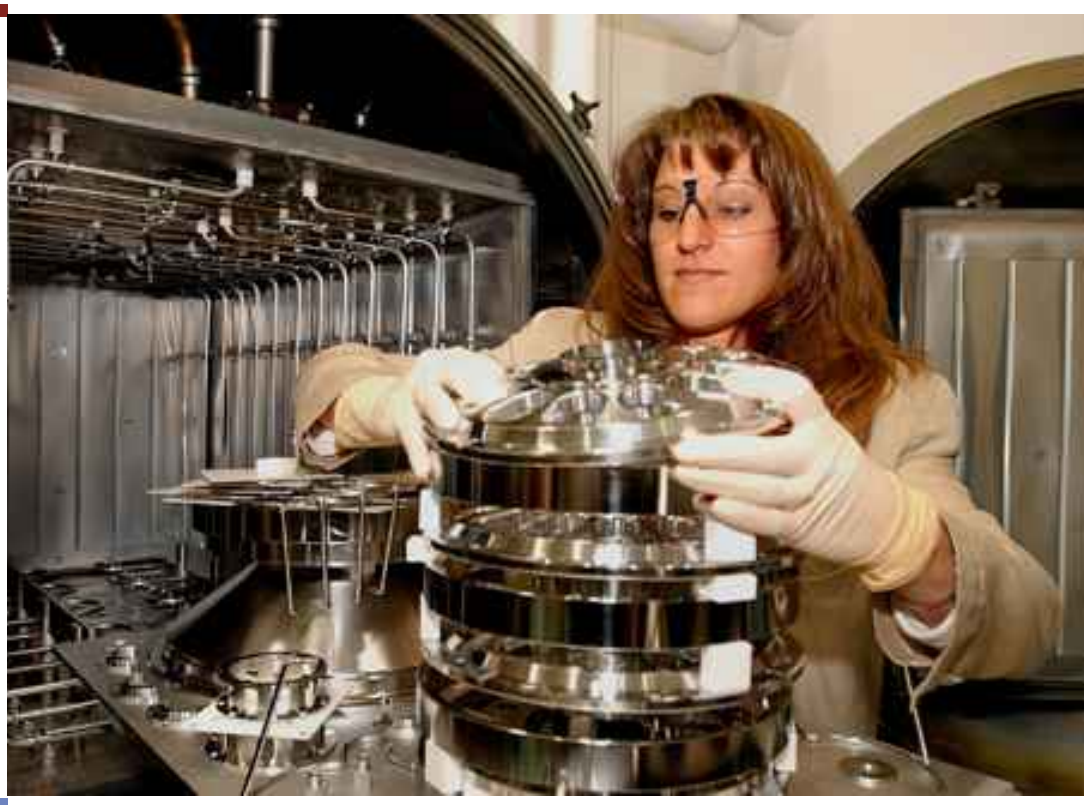
and cool operation. In some applications they also enable significant cost savings due to their lower consumption of energy. LED-based red traffic lights, for example, consume one-tenth the energy of their incandescent counterparts, enabling them to pay for themselves in as little as one year.

Thanks to the development of the semiconductor gallium nitride, bright LEDs are now available from red to green to blue light, making it possible to generate white light for illumination. Such white LEDs are now more efficient than incandescent bulbs, although not as efficient as fluorescents. However, LED efficiencies 10 times higher than incandescents and two times higher than fluorescents are believed to be achievable. As part of a Laboratory Directed Research and Development (LDRD) Grand Challenge program, Sandia researchers are exploring ways to further increase LED efficiencies, as well as to reduce production costs by more than two orders of magnitude. This year Sandia scientists improved the power output of our near-ultraviolet (UV) LEDs by a factor of 15.

In related work, Sandia is developing a small, portable detector of biological agents such as anthrax. The device will use deep UV LEDs to excite fluorescence in biological specimens such as anthrax spores. The work on deep UV LEDs (340 and 280 nm wavelengths) clearly complements the solid-state lighting work.

Sandia's work with advanced ceramics is opening many possibilities in nano- and microstructures, especially in photonics and sensors.

In past research, Sandia's photonic lattice has shown the ability to bend light with no loss of efficiency. Now a microscopic tungsten lattice—in effect, a tungsten filament fabricated with an internal crystalline pattern—has the potential to raise the efficiency of an incandescent electric bulb to something substantially larger than the 5 percent currently achieved today. In a manner similar to LEDs, this could greatly reduce the world's most vexing and important power problem—the costs to homeowners caused by inefficient lighting, as well as the environmental impact accompanying unnecessary power generation. While this approach has the potential to achieve the



Mary Walker uploads diode components into a hydrogen/vacuum firing furnace at Sandia's Z pulsed-power facility.

Hardly bigger than a bread box, this stack of embedded computer systems operates as a portable cluster computer—useful for demonstrations, conferences and road shows. The system, which won a "Work in Progress" award at a computing conference, uses central processing units similar to those found in hand-held devices and a Linux operating system.

same, and possibly greater, energy efficiencies as solid state lighting, it is a more exploratory, high-risk technology.

The advance also could mean increased efficiencies in photovoltaics—the process of changing light to electricity. Like cars that operate best on certain types of gas, photovoltaics work most efficiently when struck by light at wavelengths the material can best absorb and transmute. Computer calculations show that by using a tungsten lattice to "dial" the proper wavelengths allowed to strike photovoltaic material, the efficiency of converting light to electricity would rise to 51 percent from the 12.6 now possible using typical, less "smart" emitters.

The Amazing Z Machine: *New Technologies for Understanding High-Energy-Density Physics*

Three years ago, the Z pulsed-power accelerator exceeded its goals by producing x-ray energies more than 50 times and x-ray powers more than five times greater than any other laboratory facility. Its record output of 230 terawatts of x-ray power (lasting for a fraction of a second) is still unchallenged today, and is about 80 times the world's total electrical generating capacity. Having established these x-ray source capabilities, Sandia's contributions to high-energy-density physics have continued at a rapid pace.

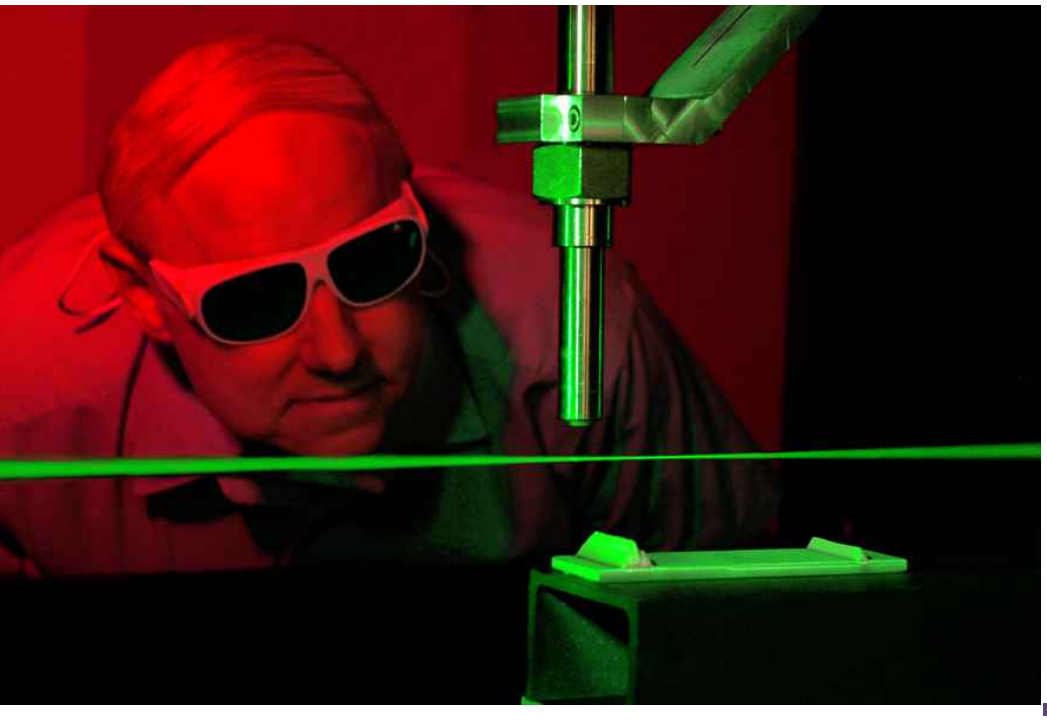
For more than 30 years, scientists have sought to under-

Polymer hydrogen getters irreversibly scavenge unwanted hydrogen gas at room temperature, improving the safety of consumer products, the efficiency of industrial processes, and the safety of nuclear material shipments.

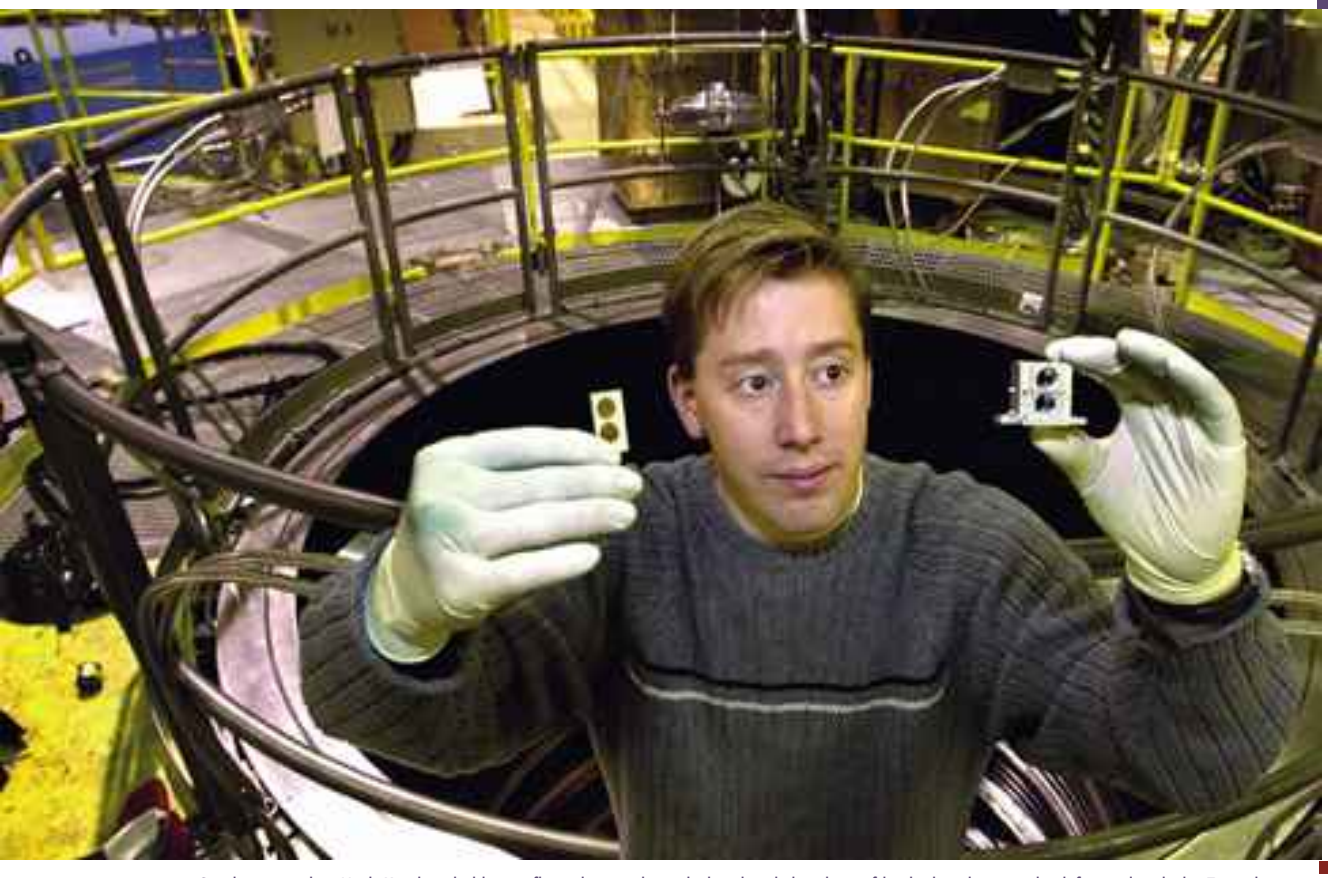
stand the nature and behavior of materials under the very high pressures of a nuclear explosion or in the center of stars. Using the Z accelerator, Sandia scientists developed a revolutionary new capability referred to as the Isentropic Compression Experiment (ICE). This technology uses magnetic fields to compress materials to ultra-high pressures without causing shocks that produce unwanted heating within the sample. The technology is presently being used to compress materials to pressures of about four Mbar (four million atmospheres of pressure) for very accurate equation-of-state (EOS) measurements. Experimental configurations are also being designed to extend the capability to even higher pressures. The resulting EOS information is critical for validating advanced material models used in weapons and scientific applications.

The technology is also being used to launch dime-sized flyer plates to velocities of about 28 km/second, or 2.5 times the Earth's escape velocity, to measure the effects of shocks on materials. This produces accurate EOS measurements for shock compression to pressures of more than 20 Mbar, which previously have been possible with comparable accuracy only in underground nuclear tests.

The ICE/flyer plate technology also addresses an important scientific and programmatic question involving the high-pressure equation of state of



Mark Smith uses what amounts to a laser version of a radar gun—a laser velocimeter system—to measure speed of tiny metal particles shooting toward the work surface during Cold Spray deposition.



Sandia researcher Mark Knudson holds two flyer plates in his right hand and chambers of his high-tech gun in his left, used with the Z accelerator to launch dime-sized pellets to velocities exceeding 44,000 mph.

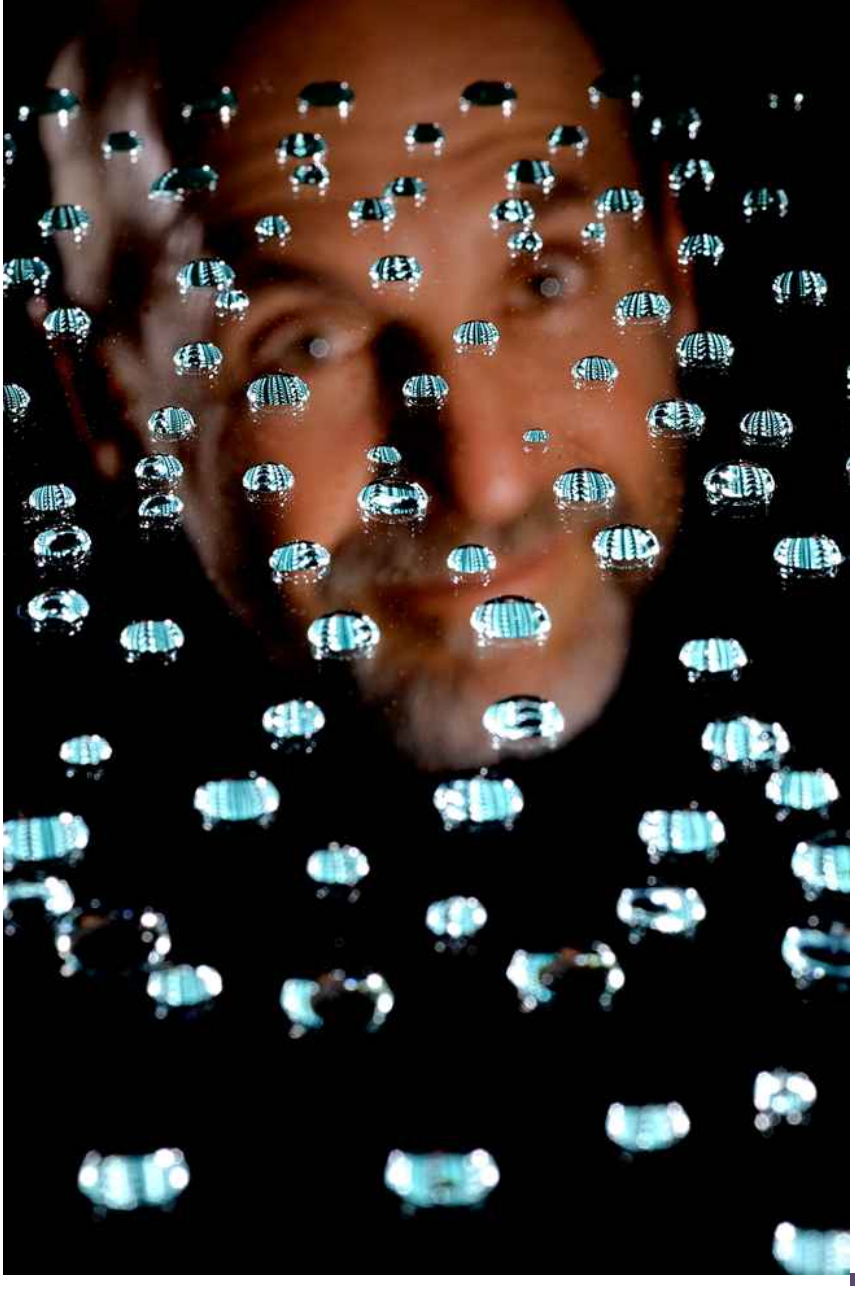
hydrogen and its isotopes. Not only is the EOS of hydrogen critical to various scientific applications, such as planetary compositions and physics, but its material response in the Mbar pressure range is critical to the performance of weapon systems. Recent laser-shock experiments produced EOS data that were significantly different from that used in the scientific community for several decades and also from recent theories of hydrogen. The different results obtained from the laser data and from *ab initio* theories of hydrogen have resulted in considerable controversy in the scientific community. The high-velocity flyer plate technology has proved valuable in addressing this controversy because it is providing highly accurate EOS data on liquid deuterium, a hydrogen isotope, to pressures of about 1 Mbar. These results, which disagree with the laser data and support the *ab initio* theories, are receiving widespread scientific and programmatic attention.

The ICE technology is being applied to a variety of other nuclear weapons stockpile stewardship applications, including determination of high-pressure equation-of-state properties, optical and mechanical properties, the effects of aging on material response, and identification of high-pressure phase transitions. The isentropic compression and associated flyer plate techniques have been available only two years but are already having a major impact on the National Nuclear Security Administration (NNSA) Stockpile Stewardship program and basic science programs in the universities. To help meet the increasing demand for these experiments, ICE/flyer configurations have been developed on the Z accelerator that permit up to 12 individual experiments to be performed on a

single Z shot. In FY02, material characterization on the Z facility was in such demand that researchers generated more than 600 individual experiment requests, but only about 200 could be accommodated.

In its first try as a Sandia diagnostic tool, Sandia's Z-Beamlet (presently the third largest laser in the world) confirmed that the Z machine spherically compressed a simulated fusion capsule. Uniform 3-D compression of an inertial confinement fusion capsule is an essential step in creating controlled nuclear fusion. It means that the x-ray energy is being uniformly delivered to the fusion capsule and is efficiently compressing the capsule, forcing its atoms closer to fusing.

Z-Beamlet images the imploding capsule in a manner that is similar to a giant dental x-ray. Using a burst of energy only a third of a billionth of a second in duration, it takes a snapshot by creating a shadow on a piece of x-ray film placed behind the BB-sized capsule inside the central chamber of the firing Z machine. The shadow, like the x-ray picture taken of a tooth, accurately depicts what is going on in the "mouth" of Z.

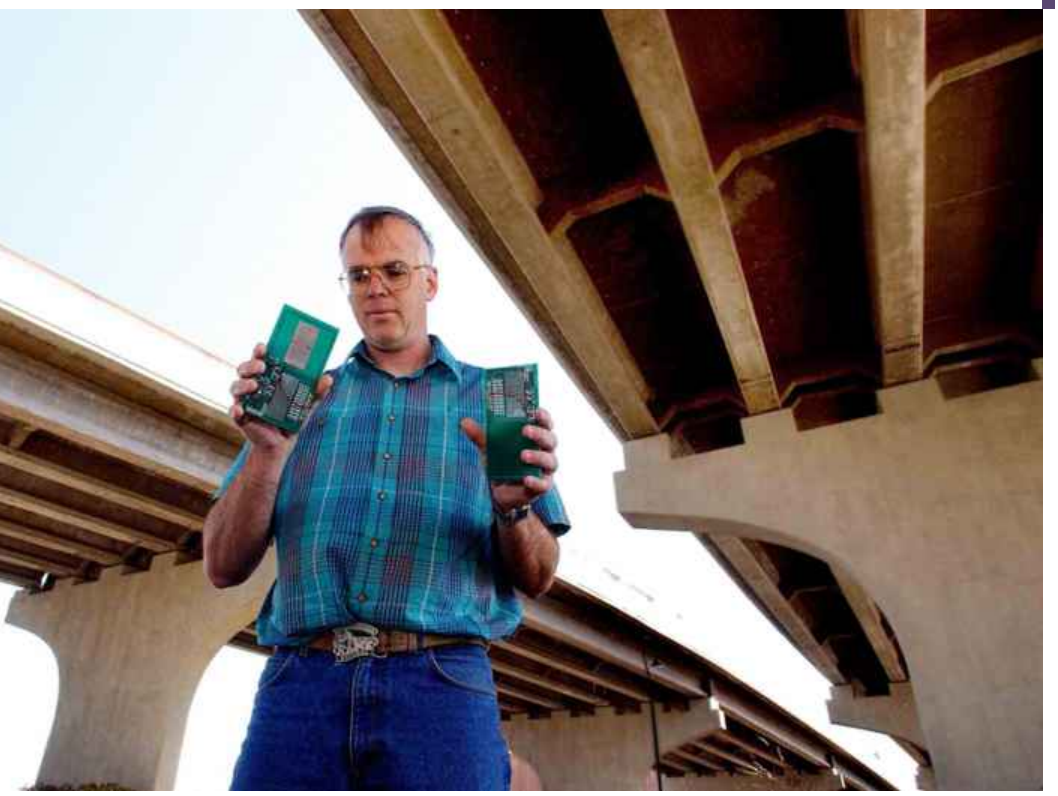


Researcher Peter Feibelman has studied unexpected behavior at the liquid-solid interface, leading to a new interpretation of water-solid interactions.

Advancements in Materials Sciences

A long-standing problem for nuclear weapons has been the removal of components for replacement or testing. Sandia developed a new, patented encapsulant technology based on a thermally decomposable polymer within an epoxy system. The encapsulant can be removed without damaging sensitive components. This technology is being extended to develop removable adhesives and coatings for electronic circuit boards.

Plastic Encapsulated Commercial Off the Shelf (COTS) electronics are being used and considered for a wide range of weapon (nuclear and conventional), satellite, and sensor applications. However, questions concerning the long-term reliability of these electronics have kept some commercial electronics



A research team led by Kent Pfeifer has designed and demonstrated the feasibility of a wireless, battery-free, vibration-powered sensor that could help keep tabs on the structural health of buildings and bridges.

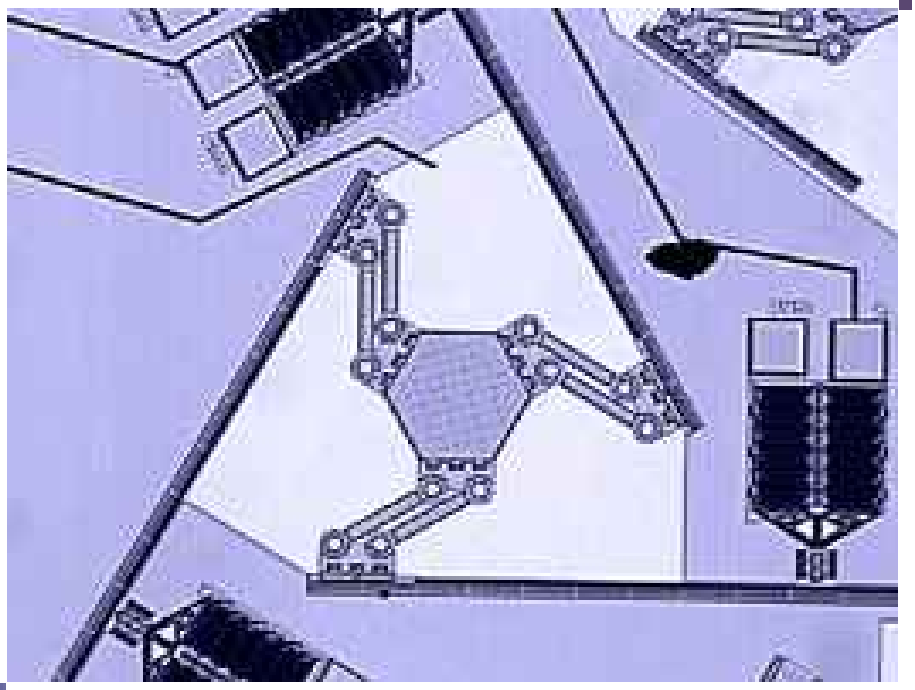
Keith Snyder's patented shielding system—originally designed to help protect workers at a large, high-speed weapons centrifuge—may find many post-9/11 security applications beyond what he originally envisioned.

from use in high-consequence applications. Sandia's work has been critical in demonstrating that COTS electronics have the needed reliability when they are produced using best commercial practices.

Sandia is exploring an innovative approach to improving the properties of glass, especially for buildings and other high-consequence applications. During accidents, natural disasters, or explosions, shattering glass can lead to significant injuries. Sandia is working with Penn State University on a new process, involving double-ion exchange, for improving the mechanical strength and reliability of glass. When it breaks, this Engineered Stress Profile Glass shatters into very small, harmless pieces.

Sandia scientists made a major breakthrough in the search for a lightweight, low-temperature, and low-pressure means of storing hydrogen for fuel cell automobile applications by developing a novel method for producing catalyzed complex-hydrides to store hydrogen. The starting materials are simply aluminum and sodium hydride powders. When mixed with a titanium catalyst precursor, the resulting material forms a powder that is capable of storing a record 4 to 5 percent hydrogen by weight. Hydrogen gas can be desorbed (at 1 atmosphere) in less than 1 hour at 125°C. Lightweight and high-strength aluminum alloys have great importance in the automotive and aerospace industries due to their strength both at low and high temperatures. A breakthrough in the scientific understanding of technologically vital alloys has been achieved. The new understanding of this important alloy could have great impact in the heat treatment of aluminum engine blocks and in optimizing the processing of half a billion pounds of aluminum each year.

A spatial positioner used in Sandia's SUMMiT-VTM process—a sequence of deposition, patterning, and etching steps—used to help build microelectromechanical systems (MEMs).



The world's smallest silicon microchain drive, developed by Sandia's Ed Vernon, may find applications including powering microcamera shutters and for mechanical timing and decoding.

New fundamental discoveries are also being made in the processing of materials. A new crystallographic orientation relationship in steel, the first discovered in nearly half a century, was identified by two Sandia scientists studying the processing of stainless steels. This orientation relationship will be important in understanding how stainless steels, which are widely used materials, perform subsequent to fabrication.

Biophysics and Biotechnology

Sandia researchers are pursuing a revolutionary approach to building microsystems in which functions found in biological and nanoscale systems are combined with more conventional materials and processes. The ultimate result may be the first-ever programmable Molecular Integrated Microsystems (MIMS) devices that can be used for rapid chemical and biochemical analysis in sensors and encoded optical interconnects that can route optical energy on demand. Over the past decade, Sandia has taken a pioneering role in the movement from traditional macroscale components and devices to fully miniaturized engineering systems. We are now taking advantage of microscale addressability to locally control materials properties and molecular interactions within the microsystem itself.

The MIMS grand challenge was initiated more than two years ago with the goal of developing the technical basis for the next generation of biochemical analysis and integrated optical microsystems. The biochemical analysis portion of the project is focused on new approaches to sort and separate small quantities of proteins in complex biochemical mixtures using the μProLab—Sandia's on-chip protein lab. The μProLab will preconcentrate dilute protein samples and perform on-chip biochemical separations, similar to what Sandia's "chem-lab-on-a-chip" does with deadly chemicals. Using microchannels as small as a few millimeters long, Sandia researchers demonstrated separation of six proteins and

Curtis Mowry deposits biological material to be rapidly analyzed on the "hot plate" portion of a Sandia prototype anthrax detector. Other Sandia researchers are studying alternate technologies for quickly detecting anthrax and other biological and chemical agents.

peptides in 45 seconds—one-tenth the time it would take if performed in longer capillaries, and with 1/1,000th the starting sample needed for laboratory-bench-top separations using typical chromatography columns.

Sandia researchers are developing new "smart" materials that can reconfigure themselves like living systems. As a first step, the researchers plan to use or modify key components from living systems and integrate and control those components in artificial microfluidic environments. They are looking at motor proteins—considered to be nature's means for transporting cargo within living cells—as the active components in the new dynamic nanomaterials.

In the "Genomes to Life" program, Sandia will lead one of three national lab-led projects and participate in the other two projects. The program will use advanced computation, genomic information, and other resources to take advantage of solutions that nature has already devised to help solve problems in energy production, environmental cleanup, and carbon cycling. Through a systems approach to biology at the interface of the biological, physical, and computational sciences, the program seeks to understand entire living organisms and their interactions with the environment. One goal of the Genomes to Life program is to understand molecular machines and their controls so well that they can be used and even redesigned to address national needs.

Nuclear Weapons

Preserving national security

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.

The nation's sustained support of Sandia has resulted in an unparalleled institution that conducts world-class science and engineering for the most critical national security missions. Our research laboratories and facilities for large-scale testing and computational simulation are national treasures that are helping us achieve a more secure future. This support continues today as we begin building the Microsystems and Engineering Sciences Application (MESA) complex, the cornerstone of 21st century weapons development. The National Nuclear Security Administration (NNSA) also supported other new facilities 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 and engineering solutions to national security problems with the highest degree of confidence. The nuclear weapons program at Sandia is the principal driver for a revitalized workforce and new technology development. Since the horrors of Sept. 11, 2001, many top-of-class scientists and engineers have been added to revitalize our workforce.

With each new generation of scientists and engineers entering

Dave Faucett (right) connects a data readout cable to an acceleration recorder while Phil Reyes uploads data after an experiment when a test unit was rocket-propelled along Sandia's rocket sled track. The nuclear weapons program has long used this Sandia facility to conduct vital tests.

Doug Clark demonstrates hardware components of the new Code Management System for nuclear weapons. Sandia has delivered all hardware and software components to the military, and the system is now operational.

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 older Sandians to serve as mentors.

Scientists and engineers are drawn to Sandia by the grand challenges of our work, by unmatched facilities in which to conduct breakthrough research, and, most of all, by the desire to render, as their honored predecessors have, "exceptional service in the national interest." That is the heritage and continuing contribution of Sandia's nuclear weapons mission.

Tom Hunter
Senior Vice President
Defense Programs

Nuclear Deterrent Remains Strong

Sandia is first and foremost a steward of our nation's nuclear 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 that deterrent remain our primary missions, and they continue to evolve due to such events and activities as the nuclear arms reduction treaty with Russia, changing defense strategies resulting from the recent national Nuclear Posture Review, and the increasing proliferation of nuclear and other weapons of mass destruction in a post-Cold-War political environment. Many of these changes result in expanded responsibilities for Sandia and its people.

Each year Sandia independently determines whether the

B61-4 Type 3-E training system produced by Sandia is used by the US Air Force to practice weapon loading and handling operations.

A group of Junior ROTC students from an Albuquerque high school examines a replica of the "Fat Man" bomb that was dropped on Nagasaki, Japan, to end World War II. The replica is in the new location of the National Atomic Museum that opened in May 2002. The nuclear science and history museum is now located in the Old Town section of Albuquerque.

weapons of our nuclear arsenal are safe, secure, and will function as designed. We develop new technologies for weapons and for monitoring them, and produce alterations and modifications of weapons systems to maintain their capabilities. We also develop technologies and systems to train our armed forces in handling these weapons and to safeguard the production complex. This systematic and objective scrutiny of all aspects of our nuclear arsenal maintains, sharpens, and deepens our system analysis and scientific capabilities.

These capabilities, addressing every scenario of threat in a systematic way, have been extended to other threats to the nation. Thus, we are transforming from a preeminent stance as the nation's nuclear engineering lab, to the nation's preeminent national security lab. We are applying the technologies, principles, and systems developed at Sandia for nuclear surety into a much broader realm of national surety.

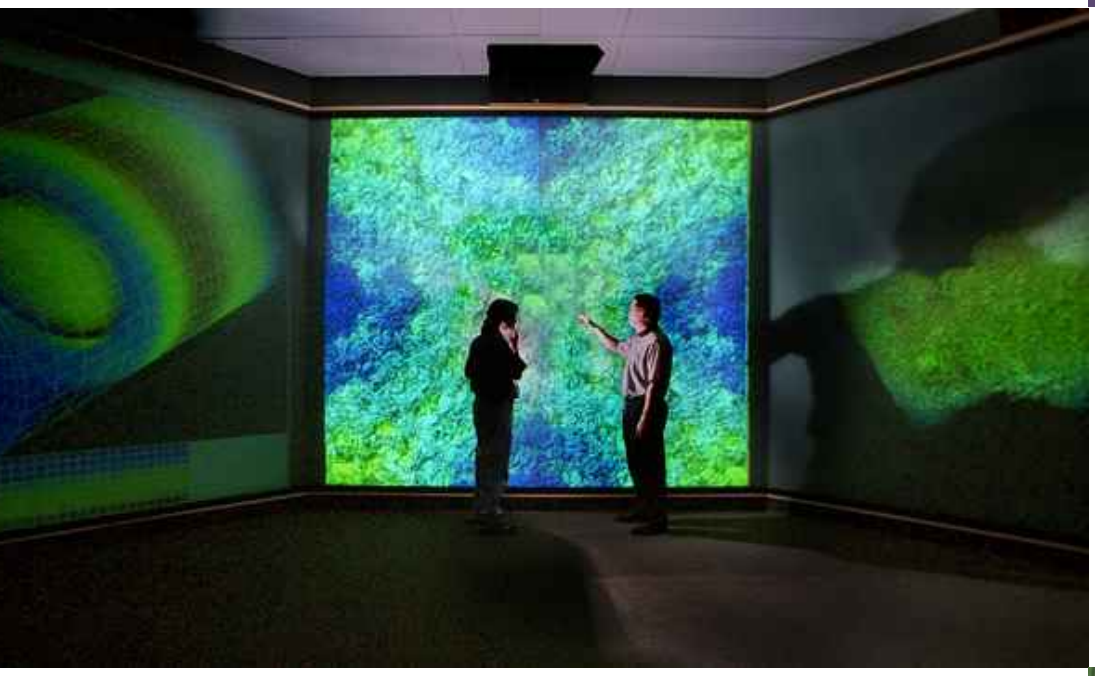
That is the challenge of becoming the national security lab, the lab the nation turns to first for its most challenging technological problems.

A New Generation of Technologies and Capabilities

With the retirement of some nuclear weapons production facilities, Sandia continues to advance our manufacturing capabilities, especially in producing new technologies to replace components that were originally designed and produced years ago with new, superior technology.

In 1992, we began producing electronic and limited life-cycle components such as gas generators and, in 1994, neutron generators. Sandia's advanced manufacturing capabilities are models for manufacturing low-volume, high-reliability parts for the nuclear weapons complex. Since 1992 we have delivered more than 40,000 components. Products include actuators, thermal batteries, igniters, gas generators, capacitors, magnetics, frequency devices, and electronic components. We have maintained a 100 percent first-time acceptance by the National Nuclear Security Administration's Albuquerque office. In many cases, through ingenuity and advanced capabilities, we have transformed components with limited shelf life to components that may never need replacing.

Since adopting Lockheed Martin's Lean/Six Sigma project management approach, the neutron generator production center has seen a 50 percent reduction in frame defects; a 66



Sandia researchers examine a complicated data set displayed with a clarity unmatched by high-definition TV. Multimillion-pixel images representing scientific data allow scientists a better view of complicated phenomena like crashes and fires.

An aerial view of the Sandia/California site is projected in the Visualization Design Center.

percent reduction in piece part and fixture packaging time; a 33 percent reduction in neutron tube exhaust cycle time; and reduction in work in process and cycle times.

Sandia's largest construction project ever, the $423 million Microsystems Engineering and Sciences Applications (MESA) complex, continues to move at a fast pace. NNSA allotted $68 million this year for engineering design completion, rerouting of MESA site utilities, upgrading of the Microelectronics Development Lab major support systems, and retooling of equipment for producing radiation-hardened microelectronics. The MESA complex will combine microsystems, advanced computation, and engineering design to create 21st century weapons and sensors for the nation, as well as to provide facilities for joint work with researchers from universities and business.

MESA will incorporate the work of other DOE/NNSA initiatives, such as:

- the computations and simulations of the Joint Computational Engineering Laboratory (JCEL)
- the computing power and codes of the Advanced Simulation and Computing initiative (ASCI)
- the communications infrastructure under development at the Distributed Information Systems Laboratory (DISL) at Sandia/California. DISL will house computer scientists, analysts, and weapon design engineers to research and deploy the advanced computing and networking technologies needed to support the nuclear weapons stockpile stewardship program.

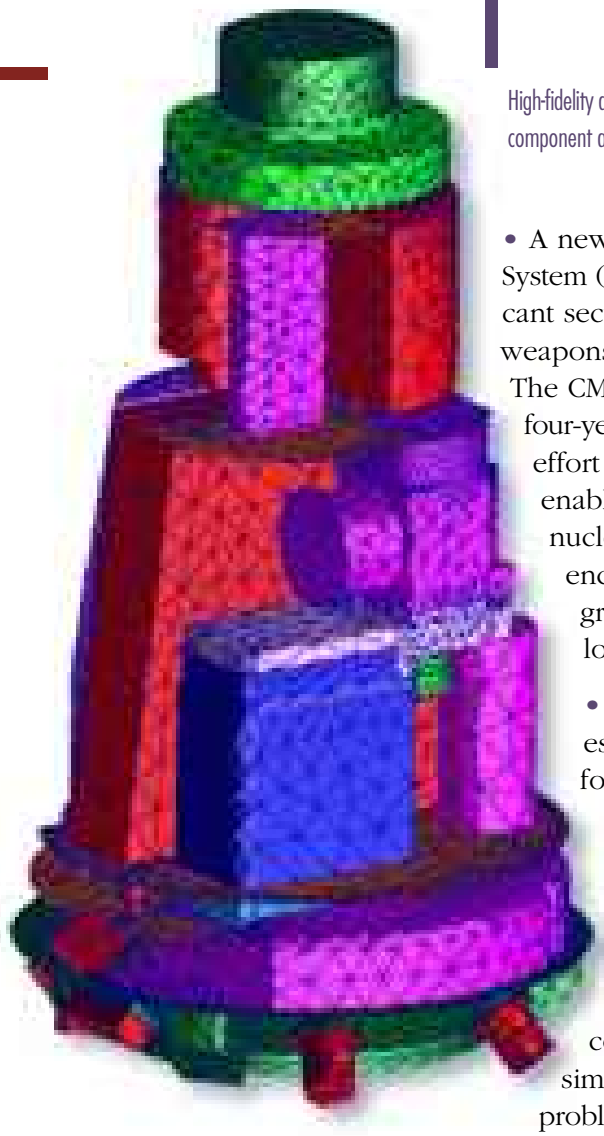
For some time we have explored microsystems technologies to enhance existing systems and enable new system architectures. Sandia is focusing on the maturation of war reserve-quality microsystems technologies and engineering methods.

This year, we demonstrated common hermetic packaging for mechanical, electrical, and optical microcomponents, precision alignment of optics, and other microsystems manufacturing techniques.

Maintaining Our Nation's Nuclear Weapons

Stockpile Stewardship

The U.S. nuclear weapons stockpile requires exact engine-



High-fidelity dynamics model of a sophisticated weapon component assembly.

ering and the integration of nuclear weapons with their delivery systems. Sandia researches, designs, and develops 97 percent of the approximately 6,500 components of a modern nuclear weapon. And we preserve the nation's capability to develop—should the need arise—new options for national defense. Sandia is also responsible for most areas of testing systems and training personnel how to handle them safely and securely.

Our successes this past year included the following:

• A new Code Management System (CMS) provides a significant security enhancement to weapons operations in Europe. The CMS project completed a four-year, full-scale engineering effort with a system that enables the recoding of nuclear weapons in a fully encrypted manner and greatly simplifies use and logistics issues.

• We continued establishing the foundations of modeling and simulation for science-based stockpile stewardship (SBSS). Using Sandia-developed or modified massively parallel computing software, we simulated complex problems such as optimal fin cant angle, contact fuse operation, and the behavior of a reentry body. These simulations involve a vast number of variables once thought beyond the realm of computation. Compared and refined with experimental data, the simulations are providing a new level of accuracy and confidence for SBSS.

• In past years, Sandia developed a number of application-specific integrated circuits (ASICs). These circuits, about the size of microchips, replace much larger printed-wiring boards (PWBs) that held individual electronic components. Modern ASICs are much better suited to withstand the hostile environment of weapons. The new, smaller units also provide more space for other *in situ* testing and diagnostic systems.

• This year, Sandia developed its first custom microprocessor architecture, the Sandia Secure Processor. With emphasis on surety, the design applies mathematically provable methods for verifying flawless, secure operation. The processor is planned for fabrication in a radiation-hardened technology in our

Marcus Knudson displays a printed wiring board created in telemetry R&D.

Artist's rendering of the Microsystems and Engineering Sciences Applications (MESA) complex. MESA is the largest construction project in Sandia's history.

Microelectronics Development Laboratory.

• We continued developing future firing and fuzing systems that contain a wide range of new technologies. These technologies included the use of micromachine and LIGA stronglinks (LIGA is a German acronym for a three-stage production process for fabricating microscopic parts), optical firing sets, and optical charging and triggering of capacitors. Through the use of simulation and rapid-prototyping tools and techniques, we were able to go from paper designs to hardware in less than a year. In addition, these tools allowed us to evaluate and solve a variety of design and manufacturing issues before prototypes were fabricated.

• Sandia has been a world leader in developing sensors that can "see, hear, and feel" substances or events thousands of times more sensitively than humans can. We continue to work on miniaturized sensors that monitor the health of nuclear weapons. The U.S. Navy W76-0/Mk4 Joint Test Assembly (JTA) redesign achieved production unit status, following a successful development flight test. The redesign replaced aging technology components in the existing 20-year-old JTA, which is used to test the continued conformance of a denuclearized version of the warhead. The new JTA collects significantly more state-of-health and critical performance data from onboard the reentry vehicle. This work has far-ranging applications in other missions, as described elsewhere in this publication.

• For training, we completed a system that the U.S. Air Force will use to practice loading and handling operations. The Warhead Simulator Package is a key component of the trainer, which simulates the electrical functionality of a real War Reserve nuclear weapon. The new trainer provides a significant improvement by allowing military personnel to realistically practice performing lock/unlock and prelaunch arming/safing operations without using a real nuclear weapon.

Stockpile Life Extension Programs

• The W76 Trident and W80 cruise missile Stockpile Life Extension Programs (SLEPs) challenge Sandia to achieve technical innovations and employ new modeling and simulation tools. Sandia is developing new designs for the electrical systems, neutron generators, gas-transfer systems, and several new structural components. We also must achieve significant improvements in surety. Sandia designs and validates new War Reserve quality components that employ technologies often many generations ahead of the previous ones. These new technologies are far more reliable and many times lighter and smaller.

Archie Gibson, operations team leader for Sandia's Corporate Computing Facility, inspects the ASCI Red supercomputer.

• The W80 program is the first to be based at our Livermore, Calif. site, bringing new challenges to our workforce there. These programs will introduce a new generation of scientists and engineers to the daunting challenges of maintaining our national security in the face of evolving threats, without actual nuclear testing.

• Our manufacturing group accomplished a seemingly impossible fabrication task. Based on a W80 system requirement, they designed and fabricated a tube within a tube with thin wall thicknesses; created features of very high aspect ratios (diameter versus length); manufactured micro-size grooves and angled holes; and assembled the components to provide a high-pressure seal.

Meeting the Grand Challenges of Computational Sciences

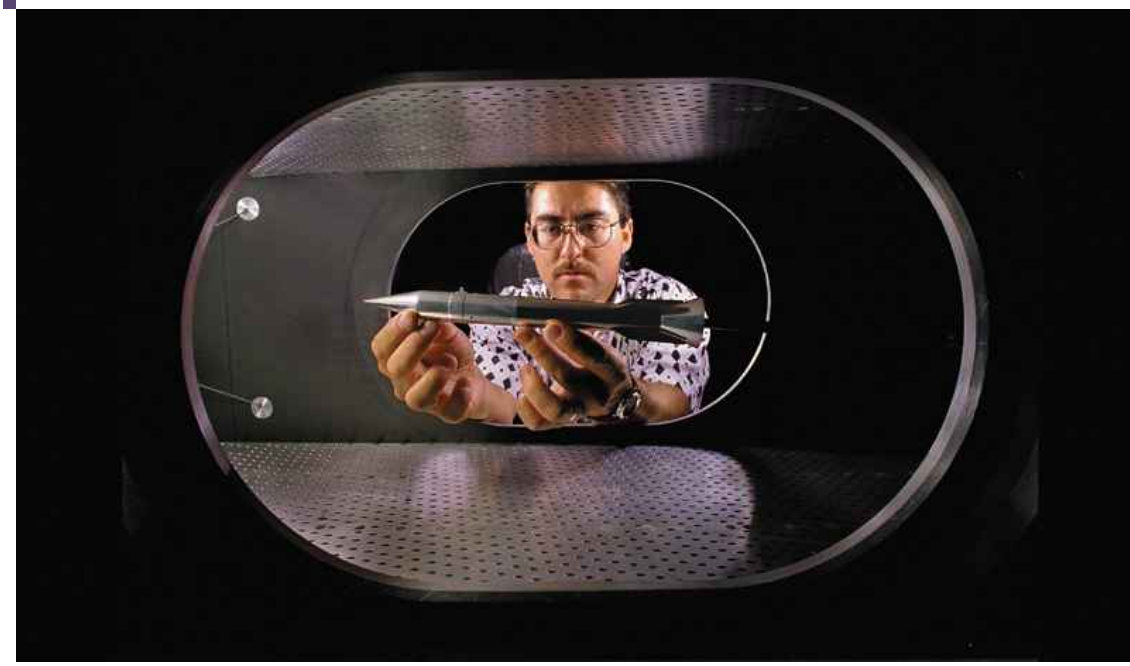
Sandia's computer expertise is world renowned. We are the only institution to win two Gordon Bell awards, presented for surmounting "grand challenges" in computer sciences. Sandia developed the science and methods for making thousands of processors work together efficiently, when most people believed only ten processors were the practical limit. We also discovered a way to computationally solve very large problems in relatively few steps, when most people believed they would take millions of steps.
This year we continued our progress on many fronts:

• Advanced Simulation and Computing (ASCI) is on path to achieve a revolutionary advance in computing power—100 trillion calculations per second (100 TeraOps) by 2006, or about 333 times faster than the approximately 300 billion calculations per second achieved in 1996. In 2004, Sandia will complete its 20 TeraOps "Red Storm" system, seven times as powerful as our current supercomputer.

• Last year we developed a high-performance computer graphics rendering system to handle the large datasets generated by the ASCI supercomputers, which exceeded the capability of previous computer graphics systems. Sandia used $350 PC graphics cards to build a scalable rendering system that performs 100 times faster than the largest commercial system, thus surmounting one key challenge of the ASCI.

• Still, efficiently storing and moving hundreds of terabytes of information across networks remains a second key challenge. A demonstration showed that the next generation network and storage technology would allow researchers at national laboratories to remotely share complex 3-D rendering of massively complex calculations.

• We also participated in the Distance and Distributed Computing (DisCom) Project. The Tri-Lab (Sandia, Los Alamos, and Lawrence Livermore national labs) ASCI Grid is the world's



Sandian Ken Chavez holds a wind-tunnel model of the B61-11 weapon.

largest computational grid with the most processors (24,548) and highest compute capability (19 TeraOps). Grid services enable both local and remote users to effectively use various ASCI resources from their desktops.

• Sandia continues work to modify the Intel Pentium® microprocessor to make it capable of surviving the radiation of weapons and deep-space environments. Intel granted Sandia a fee-free license, saving taxpayers millions of dollars. The "hardening" of ever-smaller and more sensitive chips is one of Sandia's longstanding contributions to national defense and aerospace industries, and Sandia expects to complete hardening the Pentium soon.

• Sandia's Cplant team developed a scalable architecture for continued computing expansion, and a testing strategy to ensure a quality environment for the users. It is now a tri-lab computing resource, extending its access to sister labs and to the open community. Cplant, short for Computational Plant, is now the largest Linux cluster in the world with nearly 2,000 Compaq Alpha nodes. This inexpensive, scalable and "home-grown" computer now ranks 30th on the Top 500 list of the world's most powerful computers and is the world's largest and most productive self-made supercomputer.

• Sandia computer scientists also built a cluster computer small enough to fit in an airline storage compartment. Using computer elements that are normally embedded in automobiles and home appliances and thus many times smaller than general computer chips, they showed that cluster computers don't need a football-sized field to perform large calculations.

Keeping Our Lab Secure

Hacking cyberspace is a growing international problem and Sandia is always an attractive target. Agile intrusion-detection processes, new firewall management procedures, network scanning, switched high-speed networks, and the Sandia Common Operating Environment have produced a robust cybersecurity architecture that has withstood the test of numerous audits and reviews. Viruses, Internet attacks, attempted intrusions, and unauthorized access are subject to rigorous scrutiny and rapidly dealt with when detected. On-line procedures, rapid response teams, and a sophisticated cyberarchitecture have created a state-of-the-art system designed to provide Sandia an effective cybersecurity posture. Our Intrusion Detection System Laboratory has been credited with capturing and identifying a number of Internet attacks, including the damaging "Code Red" worm.

Nonproliferation & Materials Control

Making the world a safer place

While arms reduction treaties between the U.S. and Russia will reduce standing arsenals, the threats of nuclear proliferation remain, as do threats from other weapons of mass destruction. Law-enforcement agencies around the world have seized more than a dozen shipments of illegal, weapons-grade uranium or plutonium since the breakup of the Former Soviet Union (FSU). The Nuclear Posture Review, produced by the Defense Department in late 2001, recognizes that 12 nations have nuclear weapons programs, 28 nations have ballistic missiles, 13 nations have biological weapons, and 16 nations have chemical weapons.

Sandia's Nonproliferation and Materials Control Program develops technology and methods to enhance security and support U.S. policy worldwide. We work with the FSU to protect and track nuclear materials from dismantled weapons systems and to provide scientific employment for weapons scientists. We support treaty verification with other countries and develop new technologies for aircraft and satellite deployment to detect and characterize proliferation activities in nuclear, chemical, and biological weapons. We are developing and evaluating physical-protection systems that include sophisticated technologies that can be employed both at home and abroad. Much of our technology also is being applied in homeland security efforts and in the war on terrorism.

Sandia has successfully supplied technologies for the dismantlement of many thousands of nuclear weapons. We have installed modern physical protection systems and controls at many facilities that store weapons and materials, thus securing even more thousands of weapons and many hundreds of tons of materials. As we discover and secure weapons materials, and thwart attempts to take them from safe storage to potential attack, we will continue to bolster our nation's vigilance.

K. David Nokes
Vice President
National Security &
Arms Control

Search and rescue dogs at the World Trade Center site were fitted with a mini-cam system that Sandia evaluated before the Sept. 11, 2001, terrorist attacks.

Richard Sparks displays a K-9 collar camera that Sandia evaluated, along with a TV video monitor/receiver kit, for the National Institute of Justice. The system was used to help search the World Trade Center site after the Sept. 11 terrorist attacks.

'Waging Peace' with Technology

Political dissuasion, negotiation, and international agreements remain the first means of preventing the global spread of nuclear and other weapons of mass destruction. But carrying out that diplomacy depends on the development of technologies that can accurately detect, categorize, control, and assess proliferation dangers. Developing and helping to apply those technologies is Sandia's role.

Sandia's nonproliferation technologies range from microscopic instruments to large intelligence-gathering systems that monitor the globe. The technologies keep track of the thousands of weapons in existing stockpiles and help to enforce international treaties. They also monitor the greater dangers of theft or diversion of nuclear materials and of biological and chemical weapons production and, potentially, their use.

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 the knowledge needed for strategic decision making. Beyond developing technology, Sandia supports the United States and international agencies by applying its nuclear and systems expertise in a wide variety of intelligence programs and vulnerability assessments. As the systems integrator for the nation's nuclear arsenal, we apply our accumulated knowledge to foreign technology assessments, to our intelligence community, and to worldwide problems such as cyber security of critical information and global communication systems.

The Altus unmanned aerial vehicle.

Sandia is a major participant in developing satellite surveillance technology for national defense purposes. This "antenna farm" is part of the nation's new space-to-ground communication path for nuclear detonation detection.

International Security

Raising the Technological Barriers

Sandia develops technologies and systems to counter the increasing nuclear dangers of the post-Cold-War era. For decades the design and manufacture of a nuclear weapon has been well within the grasp of industrialized societies, as demonstrated by India and Pakistan in 1998.

The biggest barrier to developing a nuclear weapon has been obtaining weapons materials. Sandia develops technologies and processes to obstruct or prevent that from happening at a time when international borders and the availability of advanced weapon design, production, and deception technologies have been loosened. Sandia is developing a wide range of ground-, air- and space-based instruments and systems to detect the signatures of uranium production. Producing plutonium requires large nuclear reactors, and these facilities are vulnerable to many forms of surveillance.

Sandia is playing a strategic role in the U.S./Russia arms reduction treaties. The Trilateral Initiative of the United States, Russian Federation, and the International Atomic Energy Agency, aided by senior Sandians, is developing a model verification agreement and exploring verification technologies.

Culminating four years of collaboration with the All Russian Institute of Experimental Physics (VNIIEF), we conducted a virtual ribbon cutting of the Facility-to-Facility project. The goal is to evaluate advanced fissile material monitoring and communications technologies in a bilateral regime. Two facilities, one at Savannah River Site and one at VNIIEF, are placing fissile material into a simulated bilateral monitoring regime. The results of this project will provide critical insight into the potential role of advanced monitoring and communications technologies for improved security and control of materials in the US and Russia.

Under the sponsorship of the Defense Threat Reduction Agency, we have developed a new relationship with the Russian nuclear weapons forces in the area of warhead monitoring. This multiyear project will explore monitoring concepts and technologies for enhanced warhead security and safety. The US/Russian project team has selected a military site in St. Petersburg for technology development and field trials. Results of the effort will lead to Russian-certified technologies for enhanced security and safety of the Russian stockpile.

Sandia's Cooperative Monitoring Center (CMC) is a microcosm of our international security efforts. The CMC was established in 1994 to develop

Right: Sandia's "Second Line of Defense" program minimizes the risk of nuclear proliferation and terrorism. Monitoring rail traffic crossing the Russian borders is part of this program.

Below: Under sponsorship of the Defense Threat Reduction Agency, Sandia has developed a new relationship with Russian nuclear weapons forces in warhead monitoring. Russian weapon cases are seen here being tested.

and provide information to other nations about how technologies can be used to make the world a safer place. The Cooperative Monitoring Center worked with retired military officials from India and Pakistan to develop concepts for cooperation along their contentious border. Pakistan has proposed specific ground-based border-monitoring systems to be deployed cooperatively between India and Pakistan. India worked with the Center to develop plans for cooperative aerial overflights along the India-Pakistan border. Both efforts seek to reduce border tensions between these nuclear-weapon-capable states.

Security Systems

Expanding Our Influence through Security-Systems Engineering

Sandia shares technologies for protecting nuclear material with Russia in a program that complements our support of the nation's policies on international nonproliferation. Sandia is the world's treasury of knowledge for nuclear security, having been charged for many decades with developing and implementing security for the entire U.S. weapons complex.

The theft or diversion of a few kilograms of weapons-grade materials—not of nuclear weapons, which are highly secure—is the greatest proliferation danger. Researchers estimate there are 240 to 320 metric tons of plutonium and 1,700 metric tons of uranium worldwide.

The breakup of the Soviet Union poses a continuing proliferation threat for these materials. For decades, Russia relied on a "guns-and-guards" approach to security. This method is now vastly underfunded. For the past nine years, Sandia and the Department of Energy's Office of Nonproliferation and National Security have helped Russia develop a more rigorous technology-oriented safeguards system.

Sandia's Second Line of Defense (SLD) Program has successfully initiated strategies and processes to rapidly provide integrated sustainable systems to minimize the risk of nuclear proliferation and terrorism. In Russia, 26 site surveys were performed at Russian airports, seaports, railroad checkpoints, and border crossings. These site surveys included the deployment and acceptance of SLD systems installed at eight Russian Federation State Customs Committee facilities to detect and deter the illicit movement of nuclear materials out of Russia. The program has been successful and is growing to include other key countries.

Russia's nuclear cities face many hardships, which can be mitigated with enlarged commercial and civilian ventures.

Sensor-fusion technology—which can identify obscured objects and track, for example, military vehicles to show a history of activity at a site—can support nonproliferation and treaty verification.

For example, a Sandia research project is taking advantage of advances in sensors, materials science, and microcomputers to develop an artificial limb that even more closely emulates the human leg in terms of both performance and comfort. This effort employs 120 Russian scientists who were designing weapons.

Intelligence

Using Our Technologies and Expertise to Analyze Information

For decades the grand challenge of the intelligence community has been to reduce great rivers of raw data into streams of information. Data are gathered in gigabits per second each from countless sensors, many in different formats, communicating to different receivers. The goal is to sieve these information streams in ways that help analysts gain sufficient knowledge to make accurate decisions.

Sandia is one of the world's leading centers for exploitation of massive data streams and databases. We produced many breakthroughs in the computer and heuristic sciences. Today we are developing enhanced techniques for the intelligence community, as well as advanced technologies to gather data.

The space-based Global Positioning System/Nuclear Detonation (NUDET) Detection System (GPS/NDS) is a constellation of Air Force satellites that has two missions: (1) to provide accurate navigational data and (2) to detect and report nuclear events. The second mission to support worldwide NUDET detection surveillance is provided by a sensor payload on the GPS satellites called the Global Burst Detector (GBD).

Sandia is completing the NNSA-funded GBD prototype and qualification payload units for the next generation GPS Block IIF satellites. This series of payloads includes state-of-the-art optical, electromagnetic-pulse, and x-ray sensors for the detection of NUDETs in the atmosphere and space.

As part of this technology development, Sandia has fabricated a unique event-driven optical sensor assembly for satellite applications. The assembly, packaged in a 3-dimensional cube of electronics, contains an optical sensor front end, signal-processing electronics, and custom processors to hunt out signals of interest in high-false-alarm environments. In a volume of approximately 1.5 cubic inches, this assembly is capable of ultra-high frame-rate sensing (more than 80,000 frames per second). Signal processing occurs at more than a gigabit per second of raw data, a level of performance never before approached in a package near this volume.

The ability of imaging radar from airborne platforms to "see" objects below trees and foliage was an unsolved problem for many years. Sandia is now developing a high-resolution,

Scott Ferko of Sandia's Advanced Microsystems Engineering Department in Livermore, Calif., inspects a sensor that is part of MicroChemLab/CB ™, a portable system for detecting a broad range of chemical agents and biotoxins.

3-D topographic SAR (synthetic aperture radar) that addresses foliage penetration while still providing good resolution. The system has met preliminary milestones and was scheduled for a second test flight in fall 2002.

The Multispectral Thermal Imager (MTI) satellite is a Sandia-led, multilaboratory R&D project sponsored by NNSA's Defense Nuclear Nonproliferation Office. MTI has been in orbit since the spring of 2000 and has gathered thousands of multispectral and thermal image sets. MTI has demonstrated the capability to measure absolute water temperatures from space to better than 2 degrees Kelvin and relative water temperature measurements better than hundredths of a degree Kelvin. Its multispectral capabilities are now being applied to a wide variety of problems of national interest.

The DOE AURA (Advanced UV Remote-Sensing Applications) program completed the second of three major field-test deployments to Dugway Proving Ground, Utah. For this test the AURA payload, an advanced ultraviolet laser-induced fluorescence lidar, was installed in an environmentally controlled container and configured to operate from a fixed ground location. The payload was tested against a broad range of weapons of mass destruction scenarios, and in many cases the system performance far exceeded the original design goals.

Sandia has provided its data fusion, modeling and simulation, and advanced sensor capabilities to government organizations responsible for the operation of treaty verification systems. Examples include the ability to:

- detect, locate, and identify clandestine nuclear tests based on detailed knowledge of the Earth's structure and signal propagation characteristics.
- perform detailed mathematical and statistical analyses of more than 20,000 sensor events in a test sponsored by the Air Force Space and Missile Systems Center.
- develop an improved method for evaluating the performance of an intersatellite communications system used by the Global Positioning System (GPS) satellites. This work influenced the design of future GPS satellites.

Advanced Chemical and Biological Threats

Advanced technologies, especially when they include chemical or biological agents, are potentially serious threats that terrorists and rogue nations can use to terrorize a peaceful world. In response, Sandia is developing and testing advanced technologies and systems to thwart such threats.

We have designed, fabricated, and demonstrated two portable chemical-analysis systems (the μChemLab™) that can rapidly detect and analyze toxic agents. Extensive tests have demonstrated that our devices can quickly identify specific chemical-warfare agents and biotoxins with extremely high sensitivity and specificity. Furthermore, our tests have shown that common chemicals that could serve as interferrants do not affect these

Russian scientists visit Sandia's Microelectronics Development Laboratory.

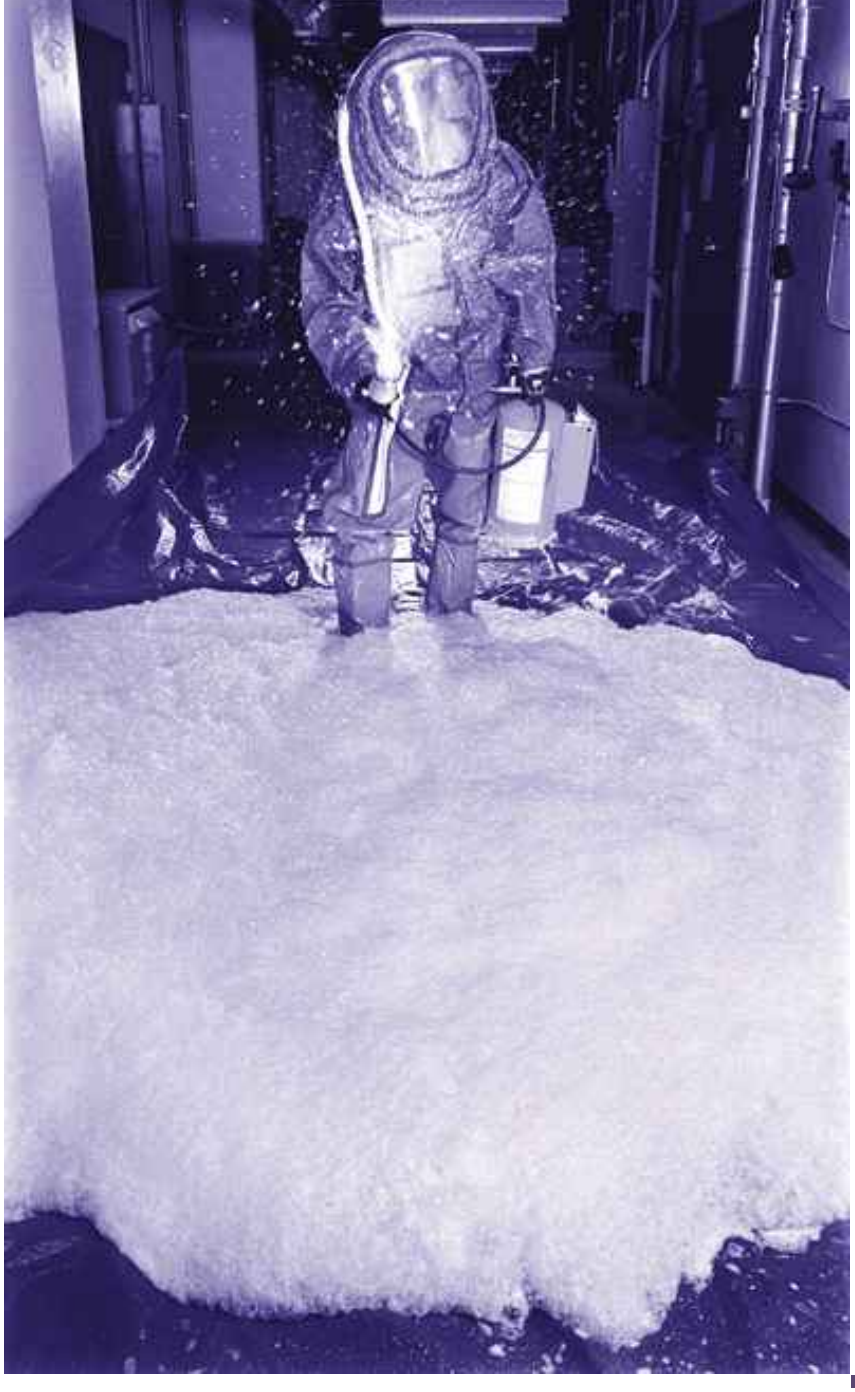
systems, now in field trials. For example, in tests at the Nevada Test Site we have demonstrated high-sensitivity detection of nerve agent simulants. In a typical test, a barrel containing triethyl phosphate was exploded, releasing a plume that traveled downwind over the sensor position. Automated analyses at three-minute intervals detected the passage of the simulant plume at sub-parts-per-billion concentration levels. In other trials, we were able to demonstrate the ability of the system to detect simulants even in the presence of high concentrations of other vapors such as jet fuel fumes. Our scientists and engineers are now developing advanced methods that will allow us to use these systems to detect additional potential threat agents, such as toxic industrial chemicals and bioregulators.

Sandia is involved in several projects demonstrating technologies to protect U.S. facilities against chemical and biological attacks.

Under the PROTECT program, Sandia has worked with Argonne National Laboratory (ANL) to characterize the dispersal of agents in subway systems, to design and evaluate distributed chemical agent sensor systems, and to develop and test emergency response systems. An integrated test of the system involving personnel from most of the concerned local government agencies last winter demonstrated that these systems could have a major role in reducing the impact of an attack on a transportation hub. We are now working with ANL to install and demonstrate a multi-station defense system.

Another project is developing systems that can be used to mitigate the impact of an attack on an airport. In collaboration with a major U.S. airport, we have used tracers and fog tests to characterize air flows in a new terminal to understand how chemical or biological agents would disperse in the terminal. Models of the facility were then developed that allowed us to assess the efficacy of various response actions, such as changing the ventilation system. The information produced by the computer simulations

Sandia has developed software systems to evaluate the dispersal of toxic agents in widely used public facilities.



Sandia's all-in-one decontaminating foam may become the best first response available in the event of a chem/bio attack. The formulation was used to help decontaminate federal and private facilities where anthrax was discovered in late 2001.

becomes extremely valuable in determining cost-effective mitigation strategies, figuring out where to put agent-detection sensors, determining sensor-performance requirements, and deciding on cleanup and decontamination tactics.

We have also established a sensor testbed in the airport and are now testing a variety of chemical and biological agent sensors, including a MicroChemLab™/CW (chemical warfare) agent detection system. This system continuously monitors for CW agents and can rapidly detect very low concentrations of individual nerve and blister agents in the same analysis. The system includes an internal standard that challenges the unit daily to guarantee successful operation.

In a team effort with the Washington Institute, Sandia has been analyzing approaches to the defense of cities against biological attack. This work was aimed at exploring optimal defensive architectures, including both protection and medical response measures coupled with detection and information coordination elements. Results are being used to guide technology-development and policy-implementation strategies. During the past year, work has focused on evaluating integrated distributed biodetection systems. The study was used to compare alternate systems architectures, detection strategies, and detector performance requirements. The results are now being used to design prototype urban biodefense systems.

Over the past three years, Sandia researchers have developed and demonstrated an aqueous foam formulation that can be used to decontaminate surfaces that have been exposed to both CW and bio agents. This material is widely referred to as "Sandia decon foam." The formulation contains only mild ingredients such as might be found in personal health-care products such as shampoo while providing very effective and rapid decontamination in seconds (CW agents) or minutes (e.g., anthrax spores). This material has been commercialized by two firms and

A Sandian demonstrates an advanced prototype of a Sandia-developed explosives-detection portal that has now been commercialized by Barringer Instruments. The technology can be used to non-invasively screen people and items for the presence of explosives. The portal performs a rapid real-time chemical analysis to screen for explosives; even trace levels can be detected.

was available in limited production quantities at the time of the anthrax attacks in Washington and New York. With the advice of Sandia experts, this material was used by local authorities and contractors to decontaminate many facilities in those cities.

Assessment of human exposure to bioweapons currently relies on pathogen replication or host responses using tests that can take days to weeks. A collaborative Defense Advanced Research Projects Agency (DARPA)-funded project between Sandia and the University of New Mexico Department of Pathology is developing methods to rapidly detect the onset of infection. Infrared data combined with sophisticated analysis tools are being used to quickly delineate cells presenting an infection-like response from healthy cells.

Explosives Detection and Destruction

Explosives-detection technology originally developed at Sandia has been licensed to a commercial firm than is now manufacturing portals to non-invasively screen about seven people per minute for explosives and a variety of other chemical residues. The portals can be used at airports, office buildings, sports arenas, and other high-traffic areas. The commercial Hound™ and Mini-Hound™, based on the same Sandia technologies, are handheld units capable of detecting infinitesimally faint traces (parts per trillion) of explosives and other chemicals.

Our first responders often wear medical uniforms—doctors and nurses will be the first to see symptoms of chem/bio attacks. But will they recognize them? Sandia's Rapid Syndrome Validation Project (RSVP) is a simple-to-use, expandable computer system, now deployed in New Mexico. RSVP provided timely information on FluType-A and RSV—a children's respiratory ailment—to physicians using the system even before a major upswing in patient visits in Las Cruces, N.M. The information augments the traditional notification of outbreaks such as those from the Department of Health and could be deployed nationwide.

Recent program advances focus on detection and disablement technologies for complex terrorist-type devices, including standoff detection and disablement of truck bombs such as the one that killed 168 people in the 1995 Oklahoma City bombing of the Murrah Federal Building, and the development of a system that screens vehicles. Sandia's Explosive Destruction System (EDS) advanced from the prototype unit that was used to destroy six recovered bomblets at the Rocky Mountain Arsenal to three field deployable units delivered to the U.S. Army. The transportable, self-contained systems can neutralize chemical munitions without burning or detonating them.

Sandia evaluated a highly precise remote-operations weapons platform for Department of Energy security applications.

Physical Security R&D

The Sept. 11 terrorist attacks increased the National Nuclear Security Administration (NNSA) and DOE focus on homeland security and counterterrorism. Sandia is the lead laboratory for physical security research and development. We provide physical security expertise to protect NNSA/DOE assets and the nation's infrastructure—and to support numerous local, state, and federal agencies. Specifically, we conduct research and development for the DOE Office of Security in the areas of intrusion detection, video assessment, entry control (including contraband and biometrics), passive and activated delay, alarm communication and display, and simulation of response force tactics.

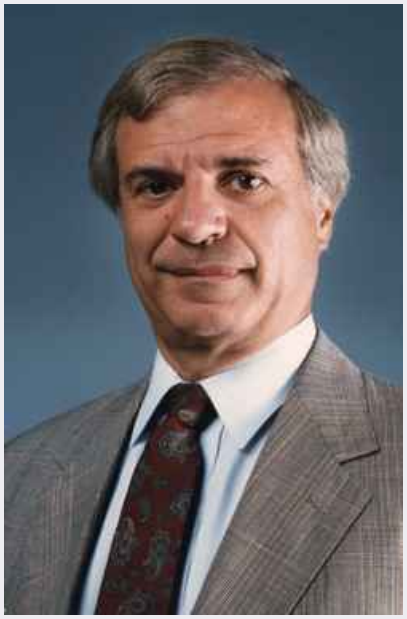
Sandia's objectives are to improve performance at reduced cost. Our Remote Response Platform will significantly improve the success of response forces while reducing casualties. Testing is under way to validate the effectiveness of the system and to exercise the command and control features. Automated calibration of explosives detection systems will assure high performance without manpower-intensive testing.

Performance testing of emerging technologies allows DOE sites to select the most appropriate physical security technology for their specific needs. We conducted biometrics testing on several human-recognition systems, including the HandkeyII, IrisScan2200, and SpeakEZ and published a report on the results. Testing is under way on several exterior intrusion detectors (Perimetrax ported coax, Intelli-Field, and LaserGuard), several interior intrusion detectors (Sentrol Model 633 PIR and Pulnix PA-480S), and the Axcess Prism digital LanCam camera. In addition, we are developing a partnership with Underwriter's Laboratories to conduct certification tests on commercial security equipment.

Security equipment must work as part of an integrated system. Therefore, we are developing the next-generation ASSESS (vulnerability assessment tool) to provide an easy-to-use, maintainable software package that can identify security vulnerabilities, serve as a repository for documentation, and support security decisions. We formed a chemical defense assessment team to develop a methodology for protecting DOE sites against chemical attack and are using the methodology to perform assessments at critical DOE facilities. We have made several assessments and suggested improvements.

Countering Emerging Threats

through technological superiority



Sandia National Laboratories has been working to maintain national technological superiority in weapons systems since its founding more than 50 years ago. This superiority will be critical in the lengthy and difficult campaign to fight terrorism and to equip our armed forces for future conflicts. Sandia is aware that national preparedness depends in part on increasing both the depth and scope of our technology-based defenses. This superiority occurs on many levels, from concepts beyond the grasps of our best futurists, to remarkable technological advances, to fundamental systems solutions, and to mundane but often resource-consuming logistics problems.

As the terrorist attacks of Sept. 11, 2001, only begin to indicate, the potential for asymmetrical warfare, as well as chemical, biological, nuclear, and information warfare, poses greater threats than ever to America and nations around the world. But advanced technologies can detect, locate, characterize, defend against, and, if necessary, destroy such threats. Sandia is working hard to develop these technologies.

The span of Sandia's work in helping our nation secure a peaceful and free world through technology is extraordinary. From basic research to global intelligence, 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

Sandia VP David Nokes holds a mock-up of an explosive to be used in a demonstration of Sandia counterterrorism technologies as he explains to Homeland Security Director Tom Ridge (third from right) what the group is about to see.

A field test determines whether Sandia synthetic aperture radar (SAR) can image military equipment in sufficient detail to identify it.

New Technologies

Protecting Our Nation and Armed Forces

Science and technology at Sandia, applied to threats against our nation, can often exceed the visions of futurists, fantasy toy makers, and science fiction filmmakers.

For many years the concept of autonomous gliding flight—an engineless glider flown on autopilot—was considered infeasible, if not impossible.

Sandia's Volant ("flying squirrel") program, operating on a shoestring budget, proved otherwise. A five-foot flying wing, combining hobby store model airplane components with Sandia-developed microsystems and miniature flight-control systems, not only flew itself but also demonstrated a glide slope, or rate of descent, that would give future gliders a range of more than 60 miles.

Utterly silent, with minimal radar, electromagnetic, density, or heat signatures, Volants of various size and capacity could provide our armed forces with new options for forward surveillance. Towed aloft and released, miniature navigation systems, including global positioning and terrain recognition systems, would guide the ultra-stealthy Volants to positions where they could deploy micro-sensors and communications systems, or weapons systems of small size but vast lethality.

The Volant program is just one of many where Sandia technologies are drawing increasing interest from the military and homeland defense authorities.

Robotic Vehicles Come of Age

Once futuristic, the success of Sandia's small robotic vehicles on surveillance missions in Afghanistan has led to an accelerated program for robotic vehicles for military and other applications.

Due to overwhelming demand for our small RATLER™ (Robotic All Terrain Lunar Exploration Rover, originally a prototype for lunar exploration), we transferred production to a commercial firm. RATLER vehicles come in a range of sizes, from 8 inches up to 3 feet long; are lightweight and maneuverable; and are able to navigate over long distances. Because of their wide usage, RATLERs have been equipped with small fuel cells that triple the range of previous battery-powered versions.

Sandia robots range from insect-like (one cubic inch) vehicles equipped with micro-sensors to large systems for coating aircraft or transferring 20-ton containers between ships at sea. Our Sand Dragon robotic vehicles demonstrated capabilities to surmount obstacles and climb stairs. Our design for a larger,

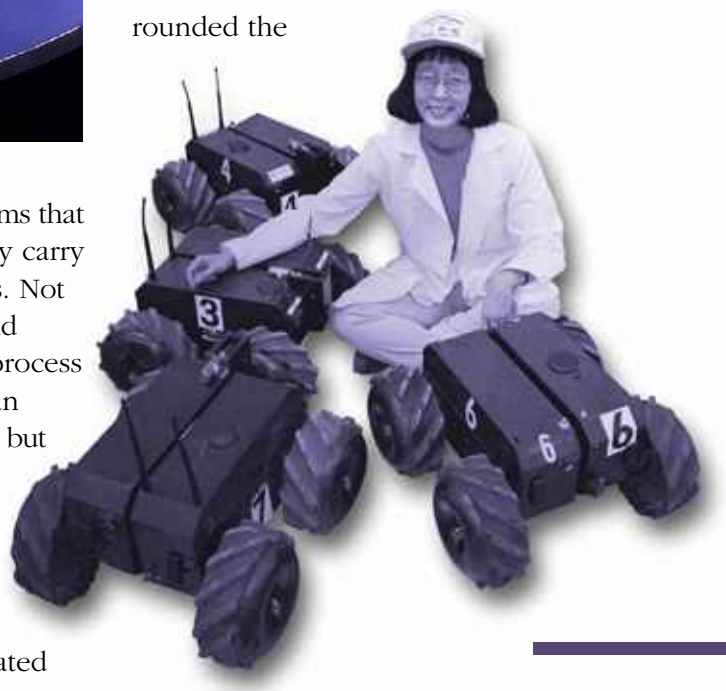
A Sandian checks out a Sandia-developed prototype robot that was studied as a possible way to inspect gas pipelines.

1,500-lb unmanned combat vehicle has received funding for a prototype.

Cooperating squads of robotic vehicles may some day be employed for tasks such as fighting forest fires, cleaning up oil spills, delivering and distributing supplies to remote field operations, and conducting a variety of military missions.

At Sandia, we are applying this "swarm behavior" to robotic vehicles equipped with a wide array of manipulators and even weapons. We integrate sensors, computers, and hardware to make highly refined systems that are able to collaboratively carry out highly complex tasks. Not only must the sensors and instruments collect and process data while operating in an unstructured environment, but the swarm must be able to communicate and then make decisions about how best to accomplish its mission.

Sandia has demonstrated swarm behavior—actually swarm intelligence—in unstructured environments. This includes the uses of mobile robots to guard a perimeter, intercept an intruder, search a building for intruders or harmful substances, and find skiers buried in an avalanche. In a Tactical Mobile Robotics program for the Defense Advanced Research Projects Agency (DARPA), Sandia demonstrated the capability to remotely surround a facility with a squad of RATLERs. To complete the mission, the vehicles had to autonomously navigate terrain typical of the desert Southwest, including crossing a deep ravine, negotiating tumbleweeds and other thick brush, and following man-made tracks. Several of the vehicles then surrounded the



Robotics engineer Wendy Amai with a small swarm of Sandia's mini-RATLER robots.

An Army chemical ordnance expert carries a sarin-filled bomblet at the end of a "hot stick" toward the Sandia-developed Explosive Destruction System, which neutralizes deadly gases and explosives.

perimeter near the rear exit of the facility while other vehicles entered the main entrance to create a diversion.

Umbra is a simulation environment with capabilities for describing and controlling multiple robots, and incorporating weather, terrain, and radio frequency interference modules. This is one of Sandia's modeling and simulation tools used to analyze concepts for the Army's Future Combat System.

Bomb-Disposal Robotics

Even before this nation was forced to a heightened state of alert, the number of bombs found across the country was staggering—about 3,000 per year. Sandia bomb-disposal robotics technology was licensed to Remotec, which has commercialized it. Now bomb squads have a host of new tools—and extensive training to handle bombs in new ways.

Sandia's bomb-disablement systems, such as the PAN Disrupter™, are used to disable explosive devices by defeating the physics of an explosion.

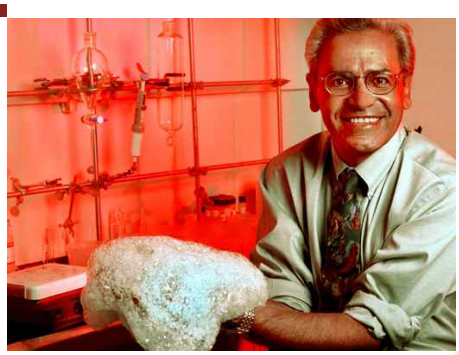
The Sandia Modular Architecture for Robotics and Teleoperation (SMART) mimics human manipulation—taking the strain off operators so they can make coordinated motions rather than twiddling a set of controls. It permits operators to perform complicated tasks, such as reaching through a car window to grab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

SMART consists of modules for more than 300 robotic instruments and controls, all of which can be put together on a computer screen, like assembling LEGO building pieces. The system then generates the computer programs to operate the custom assembly. Working throughout the modules are robotic functions such as coordinated motion, collision avoidance, video targeting, and automatic orientation, as well as basic robotics rules for movement.

Sandia has developed techniques and systems to identify, characterize, and potentially disrupt bombs from a distance in a wide variety of situations, including truckload explosive devices.

Fielding New Systems for Countering Terrorism

Sandia not only develops new technologies for national security, but also plays a leading role in working with industry and government agencies to field tools and systems in use today. From simple but effective decontamination formulations to worldwide systems for locating hard-to-find threats, Sandia technologies are playing a role as the nation defines its future warfighting and homeland defense strategies.



Sandia scientist Maher Tadros, developer of decontaminating foam for neutralizing chemical and biological agents.

Sandia has successfully tested a prototype vehicle portal that detects trace amounts of common explosives.

Defending against Anthrax

Sandia's decontamination formulation (see more information on page 33) was used to rid Senate office buildings and other federal government facilities of anthrax spores in late 2001. The foam can be sprayed quickly over wide areas. Sandia engineered the foam so that it will stick to vertical surfaces and maintain its bulk until washed away.

Working with the U.S. Postal Service, we provided technical advice drawn from our accelerator programs and longstanding work in the effects of radiation. One of the most effective ways to kill anthrax—or any biological agent, for that matter—is exposure to x-rays. X-rays leave absolutely no residual effects, apart from dead organisms. The Post Office is relying on Sandia expertise on what dosage of x-rays is most effective, and how best to implement an irradiation system without slowing mail deliveries.

Stand-off Chemical and Biological Detection

The ability to rapidly identify a dangerous compound from a distance has considerable benefits for responders in small accidents as well as those helping in regional catastrophes. Too often, first responders lack the proper instruments and training, and can become victims themselves.

Standoff technology is used in the Polychromator™, a microsystems-based technology that could be built into a soldier's binoculars to safely allow him or her to detect from several miles away whether a gas on the battlefield is potentially deadly. Through an innovative series of fast micromechanical and physics-based steps, the Polychromator sorts through millions of possibilities and identifies the compounds in the gas. That information could be displayed in the binoculars and transmitted to command stations. Every step of the system has been demonstrated except for movable microsystems-based spectral gratings—a Sandia microtechnology that is currently being adapted.

The Polychromator is only one of a number of technologies that Sandia has developed in

standoff detection. Light Detection And Ranging (lidar) systems use scanning methods to sweep a landscape and characterize the substances in atmospheric plumes.

Nonscanning systems provide near real-time ranging and other information. NASA used a Sandia nonscanning system to verify that the solar panels of the International Space Station were correctly deployed.

Other new sensors are based on technologies such as surface acoustic waves and fiber optics for chemicals, quartz resonators for fluids, and electrical or gravity field differences—all of which use microsystems.

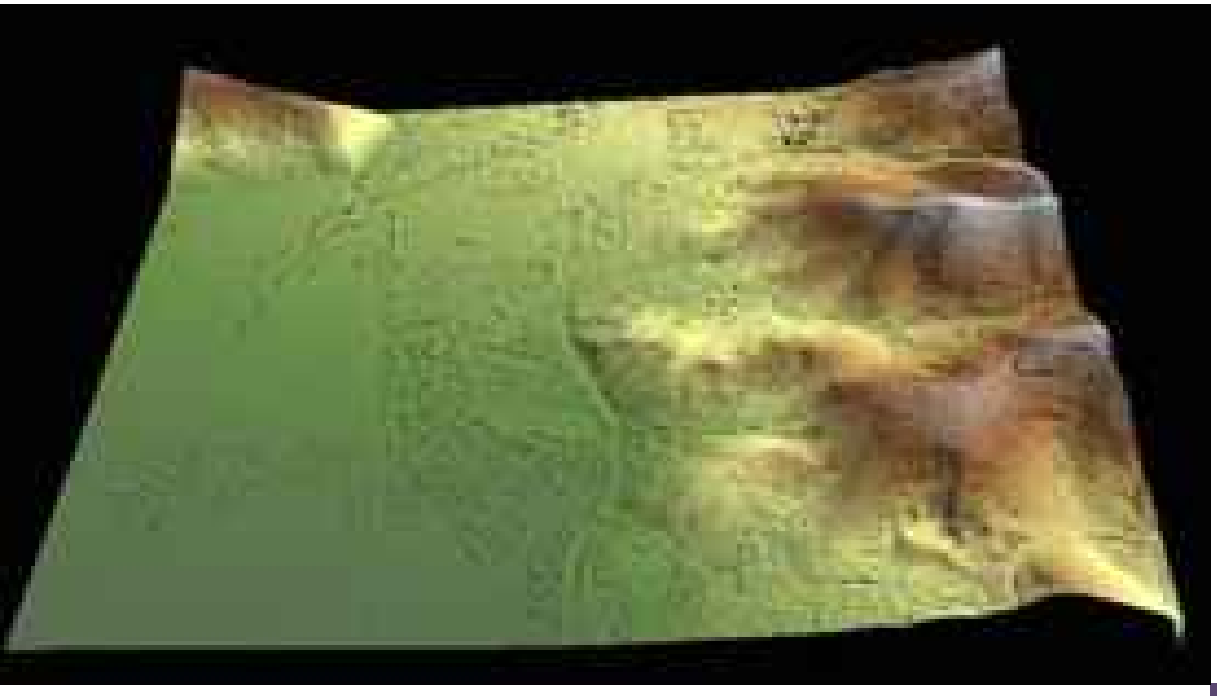
Directed Energy Weapons

The Sandia Short-pulse Laser Group achieved revolutionary physics breakthroughs in understanding propagation of high-intensity femtosecond lasers. The exceptional utility of femtosecond optical pulses originates from their short duration and wide coherent spectral bandwidth, creating unique measurement opportunities in both the frequency and time domains. Experiments and modeling identified new enabling strategies for advanced directed-energy, communication, and remote-sensing technologies.

Sandia is also developing strategic wide-band technologies that will disrupt an adversary's total communications system, and narrow-band technologies to disrupt specific data channels. Coupled with Sandia technologies for spoofing and antispoofing—deceiving an adversary's systems and defeating attempts to deceive our own—these systems will give the nation new weapons and defenses for future warfare. Sandia is helping the Air Force develop nonlethal systems that use microwave or laser technologies that will replace tear gas in dispersing riotous crowds or delaying attacks on sensitive facilities.

Hardened, Deeply Buried Targets

Sandia is developing a range of technologies and capabilities to defeat difficult targets. Difficult targets include hardened, deeply buried underground facilities



A Sandia-produced synthetic aperture radar (SAR) map of unprecedented fidelity of Park City, Utah, and environs. Sandia-developed SAR technology is used in a variety of national security applications.

Sandia is contributing to the development of a National Missile Defense by preparing targets that test the ability of interceptors to recognize and engage reentry vehicles in the presence of other objects.

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.

Ballistic Missile Defense System

Because Sandia designed many of the 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. 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. This work includes development of smart, instrumented targets and decoys, launch support activities, modeling and simulation of lethality effects, technologies associated with countermeasures, and independently scoring the results of the tests. Sandia targets have been aboard all integrated flight tests so far.

Synthetic Aperture Radar

Clouds, haze, smoke, and even smog can blind many airborne-surveillance systems. Nighttime poses its own problems, requiring the use of systems with less resolution. Sandia's small, high-resolution synthetic aperture radars (SAR) now provide all-weather, around-the-clock surveillance with 3-D capabilities.

Sandia has reduced the size of SARs so that small, unmanned aerial vehicles (UAVs) can easily carry them. Hovering above a battlefield, Sandia SARs can provide 3-D field terrain maps in real time. Instead of trying to interpret terrain lines on a flat map, these maps, produced on a rubber-like material, give field commanders an immediate visual representation of obstacles. Sandia produced radar maps with unprecedented fidelity for the site of the 2002 Winter Olympics in Park City, Utah. Similar maps have been produced of Washington D.C.; Fort Bragg, N.C.; and South Korea to support Homeland Security and Department of Defense (DoD) requirements.

A landmine detection dog and handler demonstrate traditional mine detection methods. Sandia is working with several federal and international agencies to develop new technology for detecting landmines.

Meeting Logistics and Demilitarization Challenges

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.

The Apache Attack Helicopter entered service in 1986. Giving new life to existing models while performing selected upgrades to improve warfighting capabilities are the parallel paths of the Army Recapitalization Program (RECAP). Sandia has defined a comprehensive systems modeling and integration approach for the program. RECAP goals, such as reducing downtime to zero time and zero miles and technology insertion for both sustainability and upgraded capabilities, can be reached more quickly and efficiently with Sandia's proven capability to model the entire life cycle of the program. This approach can be applied to many weapons systems that are fielded or being developed.

Demilitarization

A Sandia system that uses supercritical water oxidation—essentially superheated, superpressurized water—is destroying 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.

Sandia's work in landmine detection and demining ranges from laying down a quick-hardening foam to clear a path for military vehicles, to chemical sensing preparatory to restoring larger areas to their prewar status. Landmine detection using chemical sensing methods (e.g., dogs and electronic sensing technologies) is challenged by the ultra-low levels of explosive vapors emitted by buried devices. Sandia has combined laboratory testing and numerical simulation of the transport of chemical signatures emitted from landmines to determine optimal conditions for locating buried landmines.

Energy & Critical Infrastructures

Maintaining supplies and systems

Sandia provides solutions to the complex problems of supplying the nation with clean, abundant, and affordable energy and water. The scope of research and development ranges from fundamental research sponsored by the Department of Energy (DOE) Office of Science to large-scale tests supported by U.S. and foreign governments.

We study technologies to discover and exploit energy and water resources, systems that deliver the resources, efficient processes to use resources, and the safe disposal of wastes, particularly radioactive wastes. We focus on the safety, security, and reliability of these complex systems to protect them from failure due to age, complexity, or attack.

Sandia, in partnership with Los Alamos National Laboratory, established the National Infrastructure Simulation and Analysis Center (NISAC). NISAC will provide the most advanced modeling and simulation capabilities and expertise for analyzing the nation's critical infrastructures, their interdependencies, vulnerabilities, and system complexities.

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 at our California site is a major, and highly successful DOE collaborative research center.

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

Bob Eagan
Vice President
Energy, Information & Infrastructure Surety

Sandia has long worked to ensure the safety of nuclear power facilities. Here test engineers Larry Humphries (left) and T.Y. Chu inspect a one-fifth-scale model lower head assembly before it was "tested to failure" involving high pressures and temperatures.

Joe Henfling (left) and Randy Normann show how their high-temperature electronics package can be lowered into a geothermal well. The package can function effectively to at least 250 degrees C (about 480 degrees F) and possibly higher. No one else has developed electronics that can work at such high temperatures for extended periods.

Clean Power for Peace and Prosperity

National Security through Plentiful Energy and Water

America's national security depends on efficient, reliable energy and an abundant 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 the expertise to ensure those infrastructures remain secure and reliable.

Sandia helps industry develop more efficient means of producing energy and of extracting fossil fuels from the ground. Sandia's work targets the four stages of the energy cycle: production, distribution, consumption, and recycling or disposal.

Production

Sandia is developing technologies to boost production of multiple types of energy, including hydroelectric, geothermal and solar power, and nuclear fission and fusion. Much of our work is focused on helping the oil industry with reservoir-management practices, particularly as drilling reaches deeper to tap new gas and oil deposits. One difficulty is bore-hole damage caused by compacted rock in areas such as California's diatomite fields. Reservoirs in these fields are particularly susceptible to compaction due to diatomite's high porosity. Well replacement, lost production, and abandonment costs in these reservoirs alone have exceeded $200 million.

Funded by the Department of Energy, Chevron, and Aera Energy, Sandia scientists have developed computer modeling and simulation techniques to predict and analyze the impact of various well-drilling patterns and water flooding on the integrity of wells situated in the chalk-like diatomite fields. Sandia's industry partners have incorporated these recommendations into their reservoir-management practices.

DOE-funded solar-thermal system development, integration, and testing projects have culminated in the installation of our first working Dish/Stirling solar power generating system. Sandia delivered the system to Laguna Pueblo in New Mexico, where it is supplementing diesel engine power. Dish/Stirling solar power systems have the potential of allowing remote areas to have access to power and in some cases to replace polluting energy generation sources with clean energy.

The new National Infrastructure Simulation and Analysis Center (NISAC) is a Congressionally chartered R&D group that is helping protect the nation's critical infrastructures. Sandia and Los Alamos National Lab are primary partners in NISAC.

Steve Conrad (sitting) demonstrates a dynamic water budget simulator to Sen. Jeff Bingaman (D-N.M.) during one of the senator's visits to Sandia. The simulator calculates "tomorrow's water resources" given today's policy choices.

A National Academy of Sciences report released in 2001 stated that the Department of Energy's investment of approximately $13 billion in energy efficiency, coal, and other fossil fuel research programs since 1978 had yielded returns of about $40 billion. The report noted the work of Sandia and General Electric to improve the design of the polycrystalline diamond compact drilling bit. "Penetration rates were three to five times faster than with conventional diamond bits," the report said, and the new bits last much longer, saving drillers the time and expense of pulling drill strings to replace worn-out bits. "Today these drill bits account for about one-third of the worldwide drill bit market and have sales of over $200 million per year."

Distribution

Sandia has developed a variety of technologies that help keep America's critical infrastructures secure and reliable.

We assessed the 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 assessment 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.

Standards and controls are vital to the predictable and secure flow of electrical power. Working closely with industry and utility standards boards, Sandia made major contributions toward achieving highly effective, economical methods for connecting photovoltaic systems to utility grids. Our R&D programs included 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.

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 multi-billion-dollar cybersecurity industry.

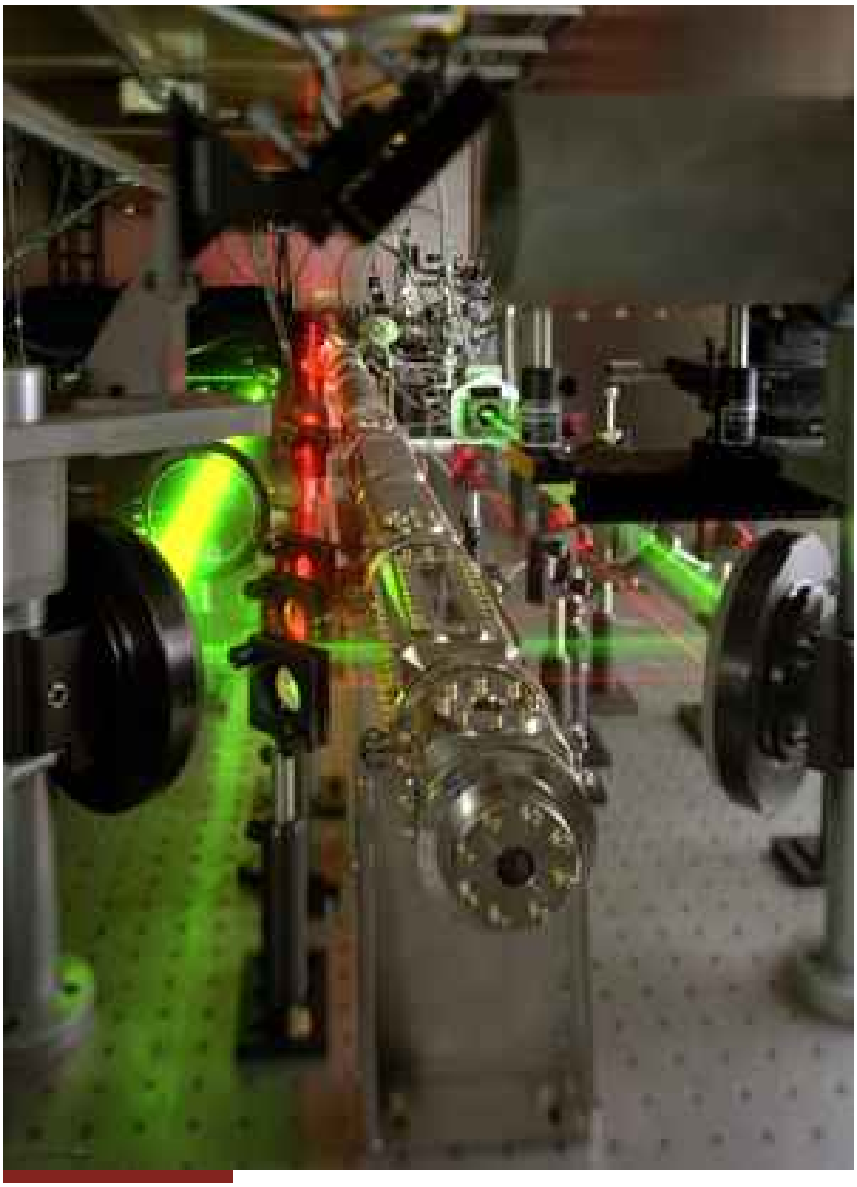
Unique electronic "sniffer" monitors volatile organic compounds in real time in air, soil, and water.

Consumption

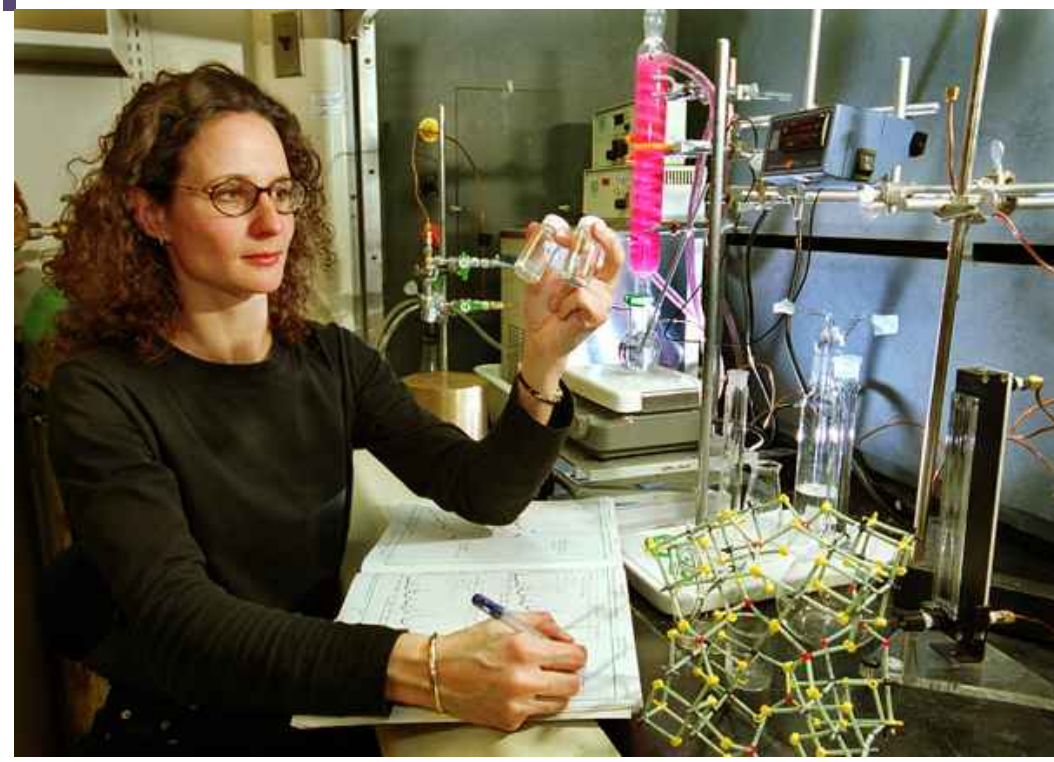
To help facilitate high-level energy and climate change policy discussions, Sandia developed laptop computer dynamic simulation models that link energy, the economy, and the environment. Current models for the United States and China project annual energy demand and carbon emissions out to 2020 and allow very rapid assessment of alternative economic, policy, and technology scenarios. The U.S. model has been widely shown and distributed, and has helped administration officials and congressional staff understand the complexity of energy policy and the difficulty of meeting the Kyoto Protocols.

Sandia is striving to bolster the effective and efficient use of nuclear power and carbon fuel energy. We have gained great insight into diesel engine combustion dynamics. Although diesel fuel burns relatively efficiently, it creates soot. Sandia has identified diesel engine design factors that create soot, and is applying that knowledge to next-generation diesel engine design. Research at Sandia's Combustion Research Facility (CRF) in Livermore, Calif., has led to guarded optimism that particulate and NOx (nitrogen oxides) emissions can be reduced at the source without sacrificing fuel economy. Collaborative experiments of Sandia's Alternate Fuels Optical Engine Laboratory with Lawrence Livermore National Lab have shown that isotope tracing with accelerator mass spectrometry (AMS) can help us understand how oxygenates affect soot formation in diesel engines.

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 because a diatomic molecule struck by an atom recoils from the collision spinning, and that energy transfer process is fundamental to how gasses heat up, cool down, and come to equilibrium.



Combustion chemistry is elucidated in experiments with newly developed laser diagnostic techniques and modeling.



Tina Nenoff examines vials of crystallized SOMS powder. Developed in collaboration with researchers at other labs and universities, SOMS (Sandia Octahedral Molecular Sieves) are "molecular cages that trap certain chemicals and may prove useful for reclaiming valuable materials from industrial effluents or cleaning up waste streams.

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 CO_2 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. Around-the-clock measurements are handled under remote control from the CRF.

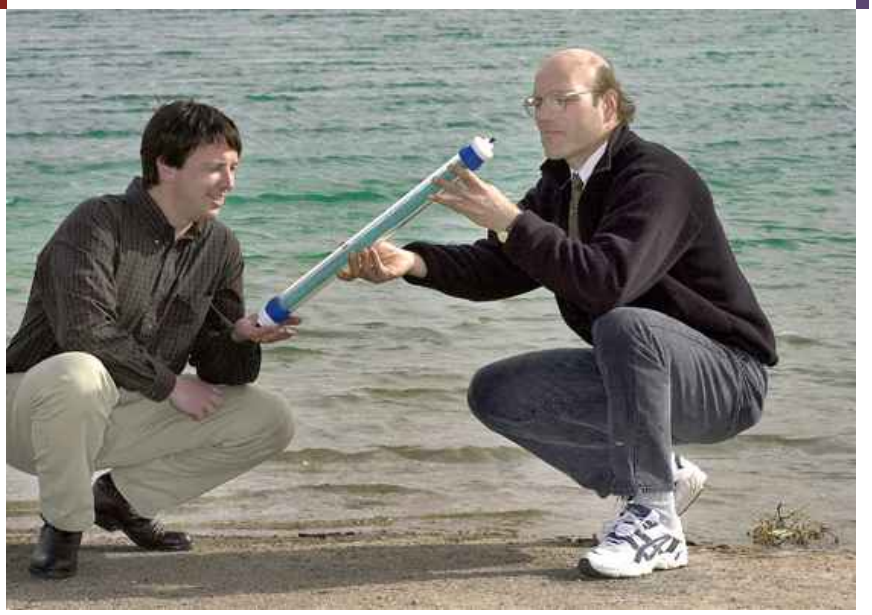
A unique electronic "sniffer" has been developed that can provide real-time *in situ* monitoring of volatile organic contaminants in air, soil, and water. A small waterproof package houses an array of chemiresistors that can instantaneously detect a large variety of volatile organic compounds. The sensor 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.

Sandia/California developed a potentially revolutionary locomotive for mines that is powered by environmentally friendly fuel cells. The four-ton commercial vehicle, originally designed to operate on battery packs, could replace diesel power, which requires expensive ventilation. Replacing diesel with hydrogen-powered vehicles would save an estimated 30-40 percent in ventilation costs, easily offsetting the cost of the fuel cells.

Disposal and Recycling

A Sandia technology that detects hydrocarbon gas leaks at oil refineries promises to help cut down on greenhouse gases and smog. The portable video imager uses some of the newest optical materials and laser technology and will streamline industry's ability to achieve Environmental Protection Agency regulatory compliance. Funded by the DOE Offices of Fossil Energy and Industrial Technology and the American Petroleum Institute, the new instrument will quickly check for leaky valves—detecting and identifying a range of hydrocarbons—at refineries and chemical plants. On the horizon, even newer engineered crystals could push the imager's operation into the long-wave infrared region, making it possible to detect more types of gases. Researchers are working on a backpack-sized system that will likely undergo refinery tests.

In a NASA-funded project, a Combustion Research Facility research team has developed a sensor that uses ultraviolet laser-induced fluorescence to detect atmospheric SO_2. Fossil-fuel SO_2 emissions influence atmospheric chemistry, air quality, and climate on local, regional, and global scales. The highly sensitive instrument measures ambient SO_2 at the parts-per-trillion level. A compact field version of the sensor being constructed uses a



Sandia technology may prove useful for reducing the amount of arsenic in groundwater, allowing it to meet strict new EPA regulations for U.S. drinking water. David Teter (left) and Pat Brady were members of a Sandia team that developed a family of formulations of mixed metal oxides called Specific Anion Nanoengineered Sorbents (SANS) that permanently trap arsenic within their chemical structures.

single-mode fiber amplifier, a technology adapted from optical telecommunications.

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 like those that accumulate inside underground storage tanks used in nuclear weapon production.

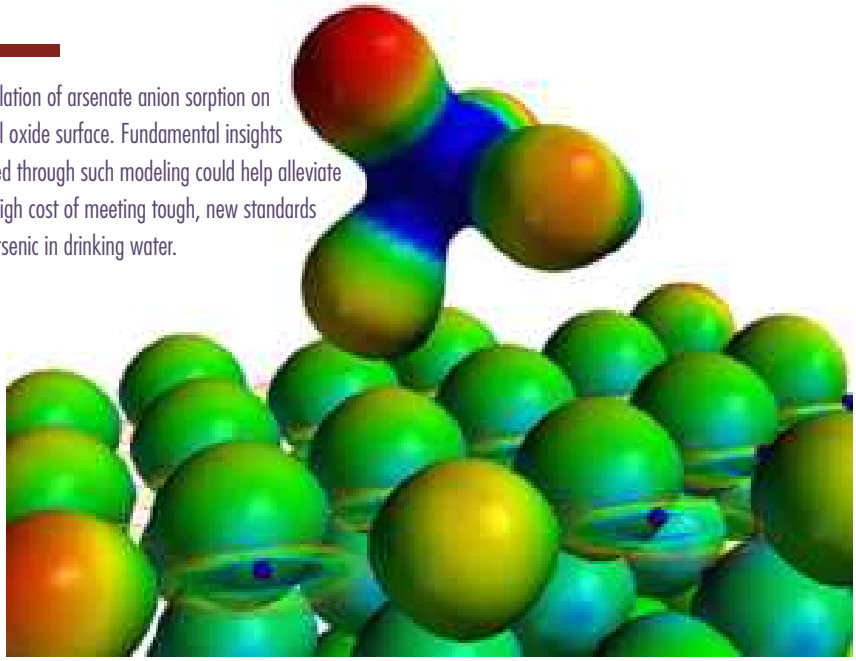
SOMS show promise for cleaning up the nation's worst environmental problem, 53 million gallons of radioactive waste at DOE's Hanford, Wash., site—the byproduct of 50 years of nuclear weapons production. The new SOMS can be engineered at the atomic scale to be extremely selective for strontium-90, one of the two most prevalent radioisotopes in the Hanford tanks and extremely poisonous to humans. Normal strontium is an essential and plentiful mineral in vegetables and milk.

In tests, the SOMS trapped 99.8 percent of strontium-90 ions in parts-per-million concentrations 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 with a perovskite crystal structure, its shrunken pores locking the strontium tightly into its impervious crystalline structure.

Some radioactive wastes remain dangerous for thousands of years. The United States plans to isolate these high-level wastes permanently in underground repositories. But before a repository can accept wastes for isolation, assessments of the facility's long-term performance must show a reasonable expectation that the repository will protect the health and safety of the public for many thousands of years. Sandia is helping to assess potential environmental contamination from radioactive wastes at several disposal sites, including the proposed Yucca Mountain site in Nevada, and the existing Waste Isolation Pilot Plant (WIPP) in Carlsbad, N.M.

Sandia was part of a collaborative team of 26 subcontractors, including four DOE laboratories and the U.S. Geological Survey, and numerous private companies, who contributed to the DOE's Yucca Mountain Draft Environmental Impact Statement (EIS). Our risk assessment recommendations were included in the revised EIS, which recommends Yucca Mountain as a suitable disposal site for high-level radioactive waste from commercial power plant reactors and government defense programs.

The Waste Isolation Pilot Plant has been receiving transuranic radioactive waste since 1999. With geotechnical studies completed, Sandia has shifted the focus to operational



Simulation of arsenate anion sorption on metal oxide surface. Fundamental insights gained through such modeling could help alleviate the high cost of meeting tough, new standards for arsenic in drinking water.

studies and is now engaged in ensuring that hazardous byproducts will be transported from the production sites to Carlsbad within the time frame specified contractually with DOE.

Sandia has developed new models for assessing future nuclear waste disposal risks, including transporting spent nuclear fuel. Our models have greatly improved the accuracy of the information available to decision-makers and they likely will become the nation's standards.

Water Safety, Security, and Sustainability

The demand for reliable and sustainable access to fresh water in the United States is fast outpacing supply. Water is becoming an increasingly precious commodity. 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 that aim to ensure the continuation of an abundant, economical water supply. 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. 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 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.

Protecting Critical Infrastructures

Sandia, in partnership with Los Alamos National Laboratory, operates the congressionally chartered National Infrastructure Simulation and Analysis Center (NISAC). NISAC provides advanced modeling and simulation capabilities and expertise for analyzing the nation's critical infrastructures, their interdependencies, vulnerabilities, and system complexities. This will lead to optimized mitigation strategies, reconstruction planning, and real time crisis support. It will allow the nation's leaders, policymakers, and infrastructure owners to actively protect the infrastructures. Sandia lends its systems analyses

Gaining a better understanding of window glasses — why they fail, how they fracture, and what might make them stronger — is the objective of a team of Sandia researchers led by Jill Glass. Shattered glass is often among the most dangerous hazards in a terrorist bombing.

abilities to the national power grid in a number of ways. 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.

Since the Architectural Surety program began in 1995, researchers have contributed much to the Labs' ability to answer the nation's call following Sept. 11 with regard to the vulnerabilities of structures to attacks.

Labs 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.

The Risk Assessment Method-Property Analysis and Ranking Tool (RAMPART) is a new type of computer application for assessing risk to federal buildings. RAMPART was developed for the General Services Administration. Users enter basic data, and RAMPART evaluates and allocates the risk arising from earthquake, tornado, flood, winter storm, hurricane, crime, and terrorism. The consequences considered are death, injury, loss of mission capability, loss of property, loss of contents, loss of use of property, and first-responder risk. Results are presented graphically.

In addition to RAMPART, Sandia has provided technologies for:

- Tests to characterize—and glazes to improve—the blast resistance of window glass
- Computer modeling and simulation of blast effects on buildings
- Providing "K-9 cams" to World Trade Center rescue teams
- Computer analysis of fire and smoke propagation scenarios through a building
- Computer modeling of chem-bio agent dispersal through a building
- Designing reliability into buildings using a systems approach

Sandia researchers are looking toward an evolutionary suite of reactor designs, each improving on cost effectiveness, safety and efficient use of available fuels.

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. 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 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.

Through all the years that nuclear power has been on the wane, 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.

The vision begins with the transformation of excess weapons-grade materials. Sandia is playing a key security role in two major efforts to reduce weapons materials in Russia. These programs are converting weapons materials—plutonium and highly enriched uranium—to use as fuel for generating electricity. In 2001 the Department of Energy announced an agreement with the Russian federation to dispose of 34 tons of surplus U.S. plutonium by making it into commercial reactor fuel. The Russian government agreed to do the same. Earlier the U.S. agreed to purchase 500 tons of highly enriched uranium from the Russians. As part of this agreement, the Russians will "down-blend" the uranium to produce material suitable for reactors, but not for weapons. Researchers from Sandia's nonproliferation and nuclear energy organizations are working to identify how different technologies in the fuel cycle impact the potential for the spread of weapons. The methodology is being used to compare the proliferation risk of advanced nuclear fuel cycles with today's once-through nuclear fuel cycle, a subject of agreement at the Bush/Putin summit in Moscow.

A Sandia-developed technique called Transparency Frameworks is being used to create a way for countries to observe one

Phil Walkington holds a piece of a composite rotor hub being tested for Bell Helicopter at the FAA Airworthiness Assurance Center that is operated by Sandia. The chopper is a Bell 206, one of several aircraft test specimens at the Center.

another and assure themselves that nuclear energy activities are not fostering the spread of weapons.

Sandia researchers are looking toward an evolutionary suite of reactor designs, each improving on cost effectiveness, safety, and efficient use of available fuels. To reach a level where 50 percent of U.S. power is provided from nuclear by 2050, with an 80 to 90 percent reduction in waste, advanced reactors are a must. The nuclear future can expect to see a movement away from the present light-water reactor technologies, which operate at high temperatures to heat water to make steam, to newer gas reactors, which generate power more efficiently. Breeder reactors actually create new fuel while generating power and will further extend uranium resources. The experimental concept of direct energy conversion, which makes use of the heavy ionization of nuclear materials to generate electricity directly from the fuel materials, is further into the future. Finally, beyond these fission efforts lies the promise of fusion.

Part of the output of these reactors will be hydrogen, the clean fuel of the future. The most abundant element in the universe, separating it from water is energy intensive, but a perfect task for reactors.

New Regulatory and Licensing Approaches

Sandia's decades-long experience in risk assessment studies for the Nuclear Regulatory Commission (NRC) is now leading to a new role for the Labs—suggesting new approaches for regulating reactors. This work applies to modifying existing regulations as well as shaping regulations that will be needed for new reactors now in design.

Presently nuclear plants are licensed for 40 years, with the option for a 20-year extension. The first U.S. license renewal application was filed in 1998 and approved by the NRC in 2000. A half-dozen other applications for renewal have followed. Experts expect something like a third of the nation's 103 power plant operators to file for renewal by 2003, with more to follow. Sandia has developed risk-informed regulation, which is a way to focus on the most important aspects of design and operations in terms of public safety.

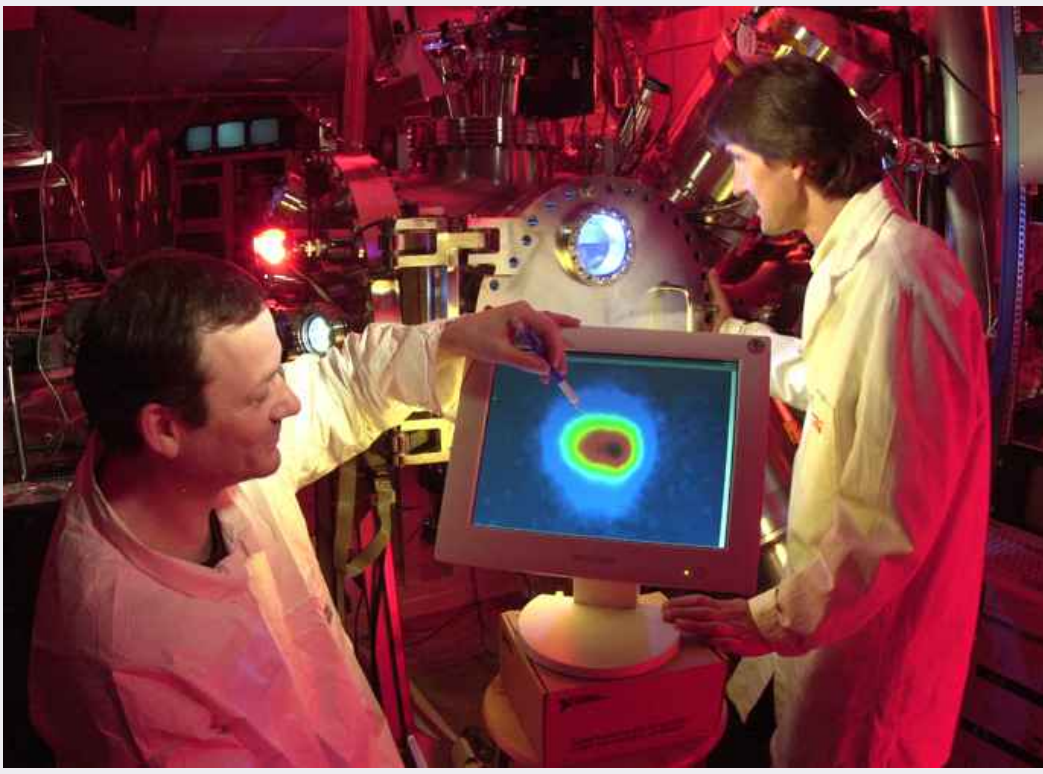
Technology Partnerships
for mission success

At Sandia, partnerships are a fundamental strategy for meeting mission objectives. Through partnerships, we develop new and refine existing technologies; we develop commercial sources and provide reliability data for mission programs; we leverage important capabilities and acquire best engineering, business, and program management practices from industry; and we create advocacy and support for Sandia. Our partners gain as well. They have access to Sandia's exceptional technology base and infrastructure, and leverage the U.S. government's investment in science and technology.

The value of industry partnerships extends beyond our primary Department of Energy (DOE) customer. All Sandia customers benefit from the leverage of cooperative industry R&D. Industry partnerships are a key element of our work with the Department of Defense, and much of our work in support of homeland security involves a partnership between a governmental entity (federal, state, and/or local) and industry.

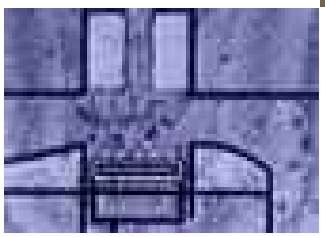
Our partnerships program is robust and continues to evolve —it is a work in progress. The program has matured significantly since Congress directed that Sandia and the other DOE laboratories partner with industry in the early 1990s. We have become more businesslike, more professional, more experienced, and more astute in our partnering practices. This in turn has provided greater value to our DOE customer. If Sandia is to continue to be at the forefront of science and technology, then partnering with the best in class must be an essential strategy.

Al Romig
Vice President
Science & Technology
and Partnerships



Extreme Ultraviolet (EUV) laser is shown to be an effective tool for next-generation chip-making equipment. TRW, a supplier to the EUV Lithography project, is developing EUV light sources using strengths in solid-state lasers and flowing jet technology.

A Sandia engineer makes fine adjustments to a complex Extreme Ultraviolet Lithography (EUVL) tool, developed by a DOE labs-industry partnership.



A Sandia-designed and -built micro-transfection device demonstrates that microelectromechanical systems' (MEMs) microscopic mechanical and fluid-handling capabilities can be used to handle individual cells. Sandia partners with industrial firms and universities to use and further develop MEMs technology. The channel between the teeth seen here is about 20 microns wide. A human hair is about 70 microns wide.

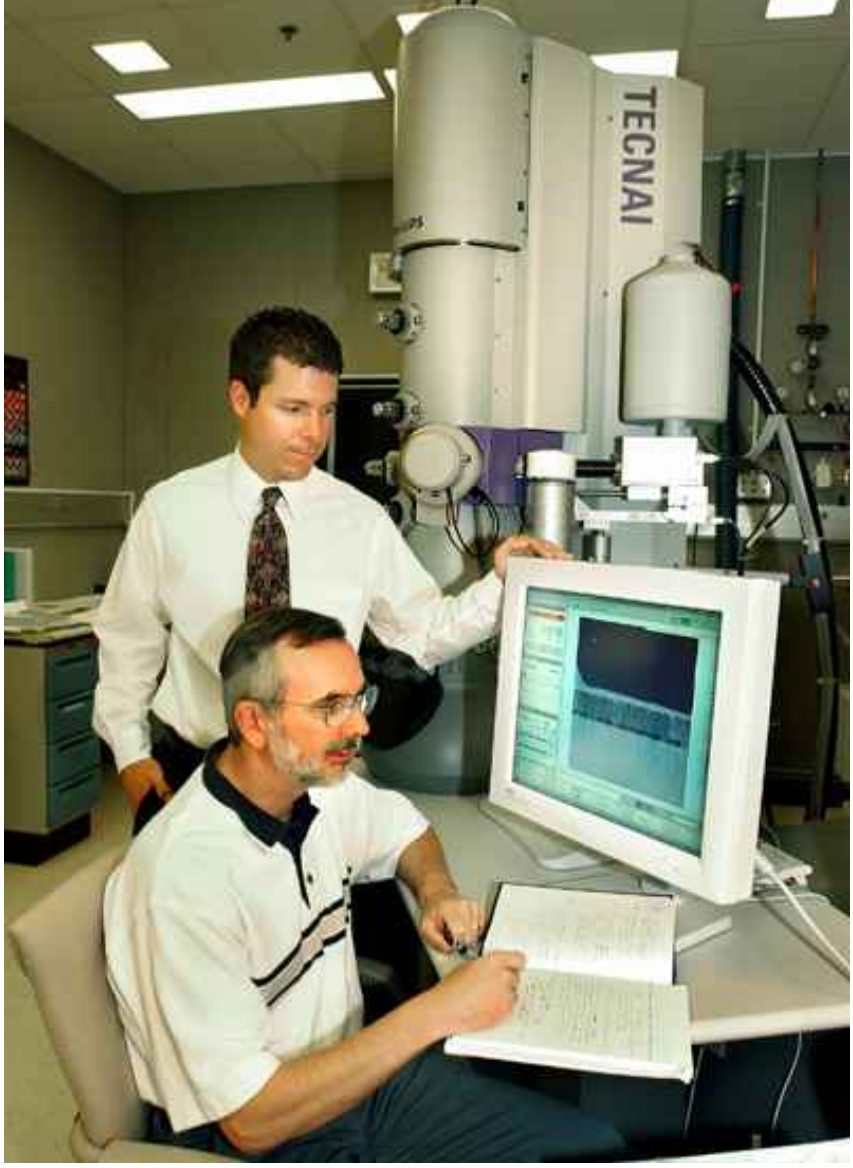
New Opportunities through Partnerships

Following are representative examples of our partnerships with industry, universities, and other agencies. More details about many of the technologies mentioned in this section can be found in other sections of this publication.

Microsystems Partnerships

Sandia continues to work with a consortium that includes Intel, Motorola, Advanced Micro Devices, Micron Technology, Infineon Technologies, IBM, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory to develop next-generation Extreme Ultraviolet Lithography (EUVL) technology. This technology is designed to produce microprocessors that are ten times more powerful than today's fastest chips, and memory chips that have 100 times more capacity. The EUVL approach is the leading contender for the next generation semiconductor lithography tool, and is favored by industry lithography experts 3 to 1 over competing technologies.

Interest continues to grow for the Sandia Ultraplanar Multilevel MEMS Technology, or SUMMiT, that produces silicon microsystems (MEMS are microelectromechanical systems). MEMX Inc., a spin-off company from Sandia, is commercializing



Paul Kotula (standing) and Michael Keenan partnered with the company Thermo NORAN to develop the Component Analysis Software (Compass), which automatically analyzes the chemistry of a micro- or macrostructure. The technology won an R&D 100 Award for innovative technology from R&D Magazine.

MEMS technology by creating commercial products for the telecommunications and other industries.

We have demonstrated the applicability of SUMMiT to biological and medical applications. For example, we have designed and manufactured a microtransfection device (a.k.a. cell Pacman) that has shown how MEMS microscopic mechanical and fluid-handling capabilities can be used to handle individual cells. Also, SUMMiT technology has been licensed to Fairchild Semiconductor's South Portland, Maine, wafer fabrication facility, resulting in a manufacturing source of high-volume MEMS devices for commercial and government products. MEMS technologies can be used to build a wide range of micron-scale devices such as sensors for automobiles, micromirrors for optical switching and projection displays, and microfluidic components for inkjet printers and chemical/biological detection systems.

Strengthening Homeland Security through Partnerships

Sandia's formulation for the rapid decontamination of chemical and biological warfare agents has been brought to market by Modec (Denver, Colo.), a specialist in mass-casualty response systems for weapons of mass destruction, and by EnviroFoam Technologies (Huntsville, Ala.). The formulation was used to decontaminate Senate office buildings and other government and commercial facilities in late 2001 after anthrax contamination was discovered.

Waters Corporation of Milford, Mass., a worldwide leader in the development of analytical technologies, licensed Sandia's microfluidics technology and launched a cooperative research and development agreement (CRADA) to further develop this expertise.

Sandia has established licensing agreements with two commercial partners, Eksigent Technologies and MCL, that will make possible further development of the MicroChemLab for chem/bio national security. This is a recent prototype.

The company is working with Sandia to develop miniaturized liquid chromatography systems. This project is a major step forward in Sandia's vision to provide portable, miniature chemical-analysis systems for national security needs ranging from the detection of chemical and biological agents to the cleanup and monitoring of environmental waste sites. We have also established licensing agreements with Sandia spin-offs, Eksigent Technologies and MCL. The technology developed will enhance the MicroChemLab miniature analysis systems for chem/bio national security needs.

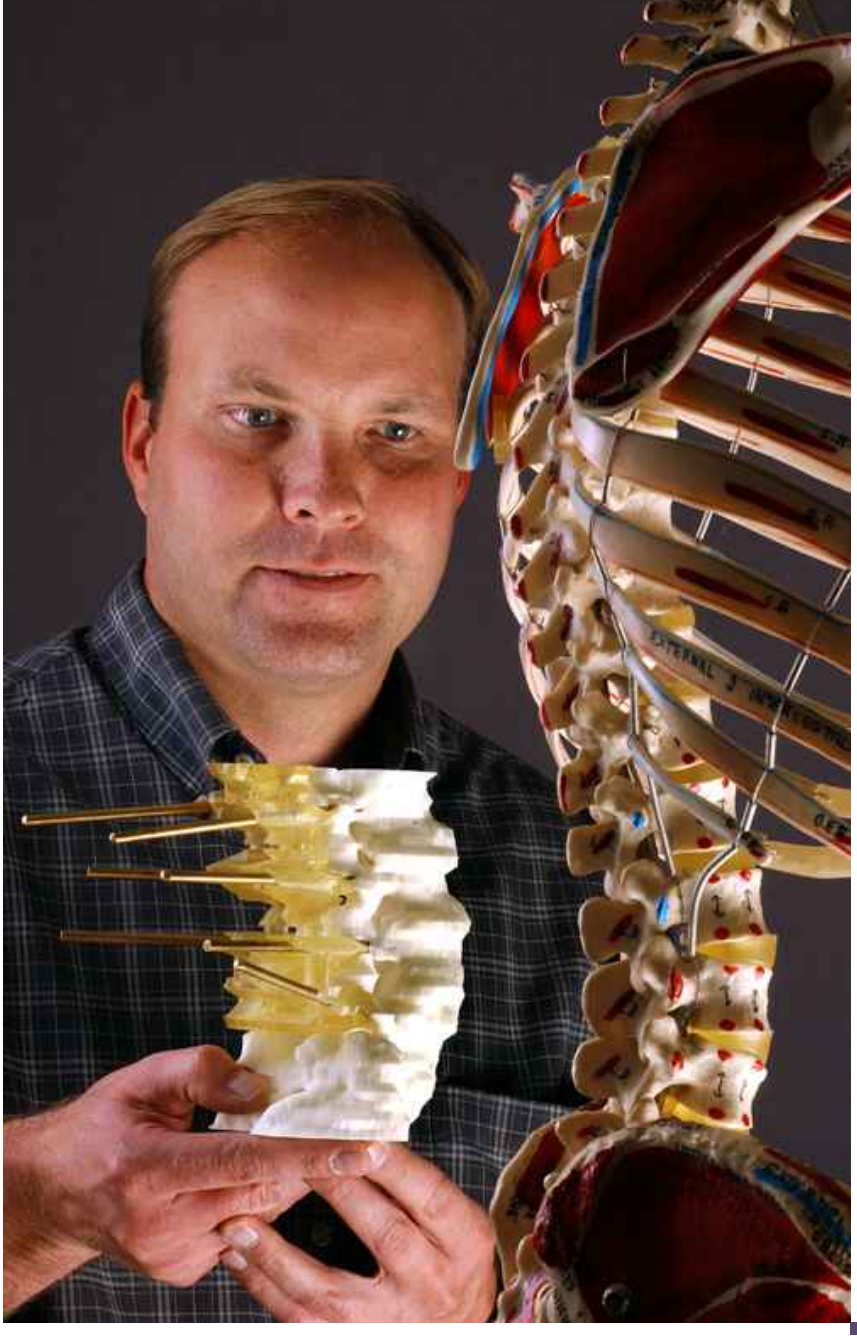
Sandia explosives engineers, working with Law Enforcement Technologies, Inc. of Colorado Springs, have developed a technique that will help police officers at a crime scene involving gunfire to quickly narrow the list of suspects to those who have recently fired a gun. Law enforcement agencies in New York state and the Los Angeles, San Diego, and Phoenix metro areas are field testing a gunshot residue detection kit that incorporates the technique.

A Sandia team is working with several agricultural universities and agencies to search for ways to apply Labs-developed technology to agricultural and food-safety issues. These include the decontamination formulation, the Rapid Syndrome Validation Project (RSVP) software for rapid reporting of disease outbreaks, modeling and computing capabilities, microsensors for chemical and biological detection in water and food, and water supply security.

Three screening portals employing Sandia-developed explosives-detection technology are being used at the CN Tower in downtown Toronto, Canada, as part of that tourist attraction's entry-point security process. It is the first use of Sandia's explosives-detection portal technology as a screening tool in a public setting. Built with technology licensed to Barringer Instruments, three SENTINEL II portals have been screening about 7,500 visitors per day (15,000 per day on weekends) at an average rate of about one person every eight seconds for each portal.

Above: Applying telemetry expertise to automatically sensing water content, engineer Ken Condreva patented a way to improve water management by checking irrigation efficiency. His device can detect water amounts of as little as one inch several feet below the surface. The device is similar to his previously commercialized sensor that automatically detects the water content of snow packs.

Left: Pam Walker demonstrates a gun-residue detection technique that police officers can use to rapidly determine whether someone has recently fired a gun. Sandia worked with Law Enforcement Technologies, Inc. of Colorado Springs to develop the technique.



Terry Litts demonstrates a template developed using Sandia rapid-prototyping technology. Fitting precisely over the target area of a patient's spine, the template allows an orthopedic surgeon to precisely control placement of screws commonly used in spinal-fusion surgery. A Sandia team partnered with a University of New Mexico Hospital surgeon to develop the template.

National Security Partnerships

Rockwell Collins, DOE production partner Honeywell FM&T, and Sandia are engaged in a cost-shared CRADA to develop a new radio frequency (RF) packaging and assembly technology. This technology will reduce costs by approximately 90 percent and improve reliability over the existing packaging technology presently used for DOE systems. Rockwell Collins' participation also ensures that the technology developed under the CRADA will be available for Department of Defense customers.

For several years, Sandia has been a strategic partner with General Atomics Corporation. This strategic partnership has resulted in the deployment of Sandia synthetic aperture radar (SAR) technology on manned and unmanned aircraft, including the Predator unmanned aerial vehicle. The outstanding image quality and increased resolution, and high radar coherence of this technology are providing the U.S. military and intelligence organizations with significantly improved real-time radar imagery.

Lockheed Martin Corporation and Sandia have formed a strategic partnership that annually funds a number of technologies related to defense and national security. The emphasis of Lockheed Martin in this partnership is systems integration, while the Sandia emphasis is in technology development. Collaborations have included work in sensors, robotics, modeling/simulation, and other defense technologies. This partnership is helping to mature Sandia technology for mission programs, and is expanding the use of Sandia technology by the DoD.

Mark Vaughn with a prototype of a unique, patented back-support system intended to reduce lower back pain in people who spend considerable time in wheelchairs. Sandia is partnering with a private firm, Numotech, which arranged for manufacture of the product in Russia as part of a nonproliferation program that provides work for Russian scientists who otherwise might be hired by unfriendly countries to make nuclear weapons.

Biomedical Partnerships

In the biomedical area, Sandia is collaborating with the University of New Mexico Cancer Center to develop computing technologies that may reveal the genetic basis of leukemia, a form of cancer that is now known to have many cellular variations. Funded by a $1 million grant from The Keck Foundation, the project team is building a microarray scanner that will be capable of making 10 to 20 simultaneous comparisons of tens of thousands of genes—a staggering increase in throughput, accuracy, and information over the current, slow procedure of one-to-one cell comparisons.

A unique cushion designed to relieve the lower back pains of office workers, motorists, and truck drivers, as well as quadriplegics and others immobilized by reason of occupation or health, is under development at Sandia in a partnership with Los Angeles medical company Numotech; a Russian manufacturing corporation, Spektr-Conversion; and New York investment banking house M.R. Beal. The patented device avoids current methods of supporting the spine with pressure, achieved by pressing the back against a pre-formed semi-rigid foam shape. Rather, in a process that resembles assisted power steering in a car, 16 pre-formed inflatable bladders aid muscles in the back intended by nature to support the spine. There is no direct contact between chair back and spine.

Getting a look at Sandia's Cold Spray™ research system are (left to right) Neville Whittle of the Alcoa Technical Center, Gregg Wagner of Siemens/ Westinghouse Power Corp., and Jeff Smith of the Howmet Corp. Sandia researcher Mark Smith, far right, shows them metal strips deposited by the system.

Below: Sandia researcher Ken Gillen (front right) discusses a tire sample with Roger Assink (seated), Mike Malone (back left) and Gary Jones.

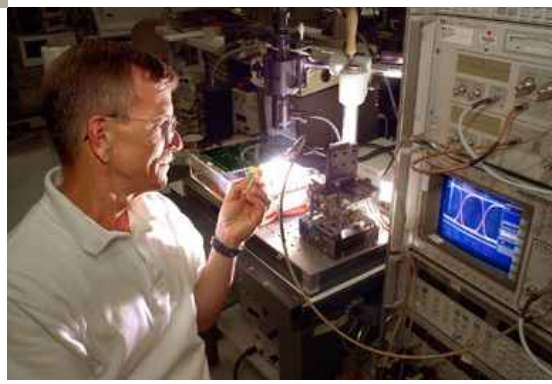
Advancing Manufacturing Partnerships

Sandia and Goodyear have bolstered their strong partnership by signing an umbrella CRADA that will allow Sandia to take on new research tasks quicker. It is the seventh CRADA signed by Sandia and Goodyear since 1993. Two initial tasks are defined in the CRADA—information management and an extension of work in current chemical research. Sandia provides its expertise to develop advanced technology tools that help Goodyear develop better tires and other rubber products faster and more efficiently.

Sandia is working with 10 industry partners to accelerate the development and commercialization of the emerging, near-room-temperature, metal-coating technology known as Cold Spray. In the Cold Spray process, metal or composite powders are accelerated to high velocities in a compressed gas jet and bond to a target surface by a process similar to explosive welding—but on a microscale. Consortium members want to use new Cold

Cesar Lombana (right) gives a tour of Sandia's robotics laboratory to members of the Southern Arizona Industry and Aerospace Association, one of the groups Sandia signed a memorandum of understanding with in mid-2002 as part of the new Regional Alliance for Manufacturing Program.

David Peterson and other Sandians partnered with EMCORE to invent the MTR8500 Very Short Reach OC-192 Parallel Array Transponder Module that promises to make very short-reach fiber optic communications less expensive. The module won an R&D 100 Award for innovative technology from *R&D Magazine*.



Spray processes to create wear-resistant coatings on car- or aircraft-engine components, for instance, or to deposit layers of reactive metals such as aluminum or copper onto substrates for use as heat-tolerant circuits.

Partnering to Support State and Regional Economic Development

In 2001, The New Mexico State Legislature approved legislation that allows Sandia to earn a tax credit up to $1.8 million a year in return for assisting small businesses in the state. Through its New Mexico Small Business Assistance Program, Sandia is providing consulting support to small businesses to help them resolve technological problems or business issues. The program's emphasis is on helping small businesses in rural areas of New Mexico. The program finished its inaugural years with outstanding results: Sandia experts participated in more than 325 projects.

Funded by the Department of Energy and the New Mexico State Legislature, Sandia continues developing the 217-acre Science & Technology Park, located next to Kirtland Air Force Base in Albuquerque. The park's fiber optics backbone became part of the infrastructure in 2002 under a $1 million grant from the U.S. Economic Development Administration. The park now has nine tenants employing 500 people. Investment in the park totals $59.6 million, including $46.4 million in private investment. Applied Technology Associates, the Sandia Laboratory Federal Credit Union, and the International Programs Building are the newest tenants.

Community Involvement

Giving back through service

A Commitment to Our Communities

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 our 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 community partners and friends, and are proud to give back through our commitment and service.

Joan B. Woodard,
Executive Vice President and
Deputy Director

Franz Lauffer gets passionate in his advocacy of education during the annual "School to World" career exploration event in Albuquerque for 8th and 9th graders.

A store employee helps some Albuquerque-area youngsters measure their feet before they select shoes provided by Sandia employees' annual Shoes for Kids program.

The joy of new sneakers lights up the face of a "customer" of the Shoes for Kids program.

Since 1993, when Lockheed Martin Corporation became our operating contractor, we have expanded our efforts 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.

In recognition of Sandia's long-standing contributions to the Albuquerque area, the state, and the nation, the Presbyterian Healthcare Foundation presented Sandia/Lockheed Martin with its prestigious Award of Excellence in the spring of 2002.

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

Thunderbird award recipient Terrance shares a happy moment with his grandfather, who helped support Terrance through some tough times after his immediate family disintegrated in alcoholism, drug abuse, and abandonment.

A worker disinfects children's toys at an Albuquerque child-care center, using newer disinfectants. Sandia assisted the New Mexico Child Care Association in various ways, including convincing state regulators that the newer disinfectants are safer than traditional chlorine bleach-based ones.

nationally through the approximately 7,700 people who make up our workforce, which generates a payroll of more than $727 million in direct salaries and contract labor. In 2001, Sandia's expenditures totaled more than $1.7 billion. We placed contracts with the private sector for $586 million in goods and services, including $289 million in contracts with New Mexico businesses and $71 million with California businesses.

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 make a difference in our communities.

• Sandians contributed more than $2.2 million to the annual Employee Contribution Plan for United Way of Central New Mexico for the second consecutive year. 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.

• 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, the deaths of parents, becoming teen parents, or living on their own. The annual Thunderbird Awards for exceptional achievement include a $1,000 grant.

• Sandians in California, through the Livermore Employee Assistance Program, donated more than $230,000 to charitable organizations. The annual charity drive has raised more than $3.6 million since 1969. In two "Holiday Spirit" drives, they also donated nearly 2,000 pounds of

Mentoring of newer employees and student interns is a priority at Sandia. Here Nina Berry (left) mentors College Cyber Defender interns at Sandia/California. Nina's dedication to mentoring earned her a national award from Career Communications Group Inc.

food and some 750 gifts for homeless shelters, children's clubs, and developmentally disabled recipients in San Joaquin and Alameda counties.

• More than 200 Sandia volunteers built a third Habitat for Humanity House, completing the home for a single mother and her two small children in a record 24 working days.

• Albuquerque's Make a Difference Day 2001 was sponsored and coordinated by Lockheed Martin and Sandia National Laboratories. About 1,700 volunteers from 35 companies completed 116 projects for 52 nonprofit agencies. More than 200 Sandia volunteers participated.

For "Make a Difference Day" at Sandia's California laboratory, employees collected more than 4,000 disposable diapers and gave them to three community shelters.

• The Office Professionals' Quality Council collected new children's books and 6,500 school-supply items for disadvantaged children during its 2002 drive.

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 provided professional-development workshops for more than 100 Albuquerque math and science teachers. Strengthening Quality in Schools (SQS), supported by Sandia and other partners, continues to serve as a

The National Atomic Museum, operated by Sandia, conducts a wide variety of educational programs for youngsters. Here a couple of would-be pilots learn some elementary flying principles from one of the Museum's volunteer guides.

catalyst for continuous improvement of New Mexico schools. Over the past year, SQS has trained more than 1,500 educators in 200-plus schools in 58 districts statewide. SQS sites continue to gain measurable results in student achievement and in improving the schools' overall system and performance. More than 1,000 elementary school students and their families enjoyed an evening of hands-on science activities as part of the Family Science Night program.

• 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 many events, including the annual Math & Science Awards Banquet for Livermore-area high school girls, the fourth annual Youth Conference on the Environment, the spring and fall Expanding Your Horizons in Science and Mathematics conferences for more than 600 students in Northern California, the Women in Science and Engineering Conference, and at the University of New Mexico's Valencia Campus Technology Fair.

• For the third year, about 250 students in grades 3-12 participated in the Go Figure Math Challenge in which Sandia volunteers administered and scored a daylong, SAT-like test, then hosted community banquets for the 62 winners.

Hundreds of Sandia employees volunteer for community projects on the annual "Make a Difference Day." This elementary school student can "visit" all 50 states during recess on this 35-foot U.S. map painted by volunteers on the playground.

To supplement science education in Albuquerque schools, Sandia volunteers partner with teachers through Crosslinks, a program for hands-on science activities.

• The National Atomic Museum's Up 'N' Atom Mobile presented almost 200 math, science and history programs (4,000 students) to schools throughout southern New Mexico during its first year of operation. The Science is Everywhere Summer Camp provided 22 camps to 400 campers, ages 8-12 at four locations throughout Albuquerque. A Taste of Science outreach program was developed to serve local schools, teaching students about radiation, space, and World War II history.

• Sandia partnered with New Mexico businesses, schools and government agencies to provide the third annual School to World career event, giving more than 1,500 New Mexico students the opportunity to explore 150 different career opportunities.

• In 2001, 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. The STAR program, in partnership with the University of New Mexico, selected 10 outstanding math and science high school students for an intensive 8-week internship that allowed students to earn college credit and work experience under the close mentorship of Sandia scientists and engineers.

• The Advanced Technology Academies and Photonics Academy received national endorsement from several national technical societies. More than 250 students participate in the academies, which offer career pathways into technical fields.

House & a hug — Sandia retiree Irv Hall congratulates Martha Rodriguez at the dedication ceremonies for her new Habitat for Humanity house built by Sandia volunteers in the spring of 2002. Martha's sons are in the foreground.

Sandia volunteers prepare to hoist a wall section into place as they begin the Rodriguez family house.

Internships at Sandia and area businesses are an integral part of the curriculum.

• Sandia coordinated the Science Bowls in New Mexico and California, a day-long academic competition for teams from area high schools. Winning teams participated in the national Science Bowl held in Washington, D.C.

Technical Assistance Programs

Sandia and volunteer employees also help communities, businesses, and government agencies address technical needs such as water and air quality, arid land issues, safety, and security.

Some of this technical assistance is done informally, by Sandians with special knowledge sharing it through their continuing participation in civic and professional organizations, community service groups, and governing boards. Other assistance is provided through more formal technical outreach programs.

• Sandia conducts workshops for school administrators, security officers, and police, teaching comprehensive approaches to school safety and the latest in security technologies that can contribute to safer schools and make them better places to learn. Sandia's Security Technologies and Resource Center also serves as an independent advisor to school administrators and security professionals.

• By 2006, a new Environmental Protection Agency regulation will require that U.S. drinking water contain no more than 10 parts per billion of arsenic. Many communities large and small—particularly in the western U.S.—have groundwater that greatly exceeds the new limit and must find affordable technology to comply with the new regulation. Sandia is cooperating with Kirtland Air Force Base to field test new arsenic-removal technologies, including some that were developed by Sandia. The results will be shared widely to help communities meet the new standard.

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