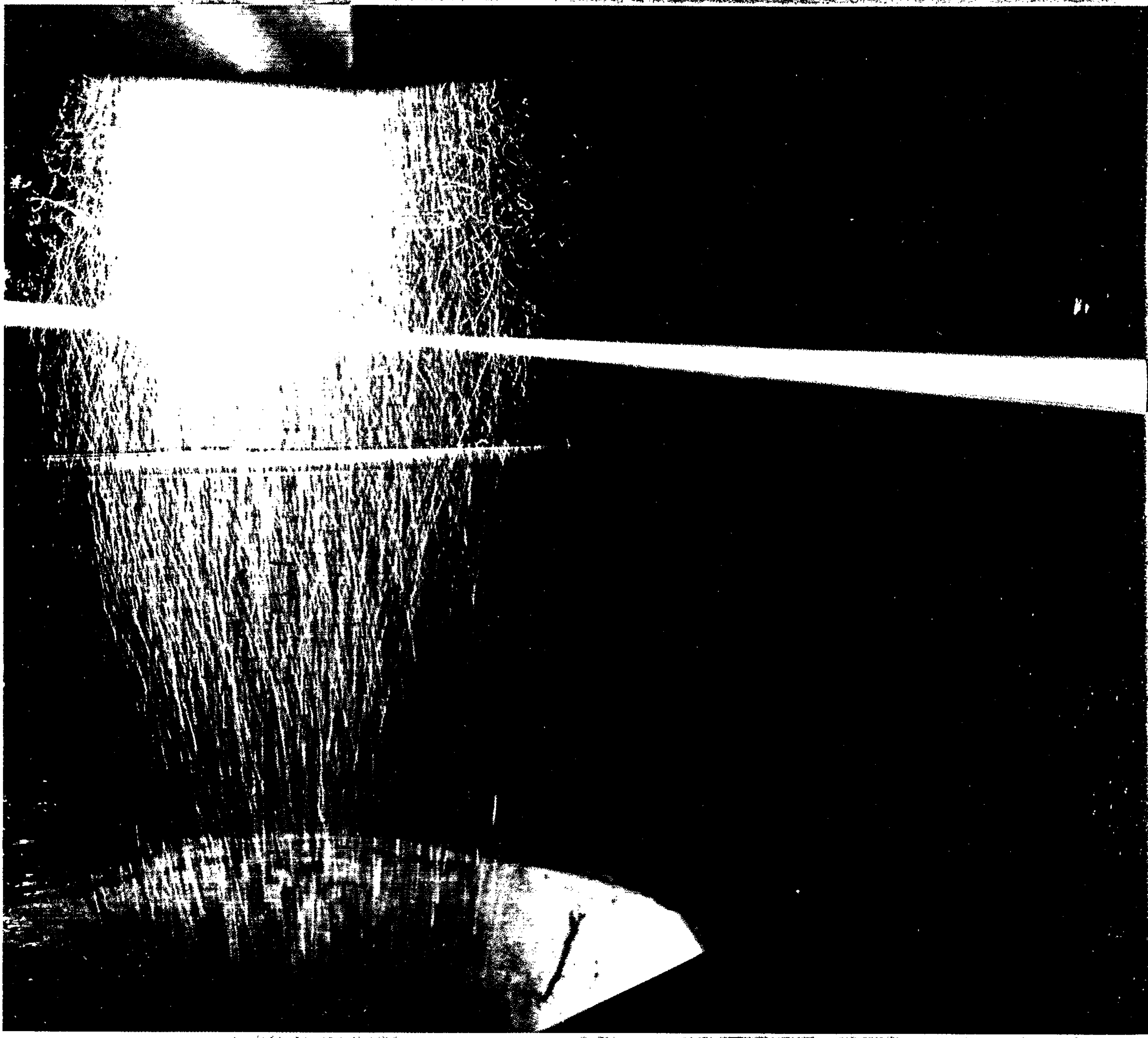
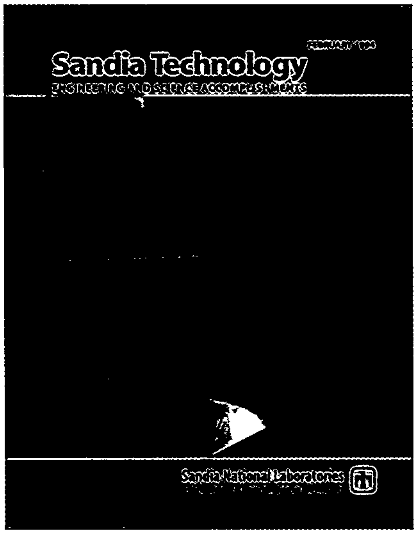
FEBRUARY 1994

Sandia Technology

ENGINEERING AND SCIENCE ACCOMPLISHMENTS



Sandia National Laboratories
a U.S. Department of Energy multiprogram R&D laboratory



On the cover:

Sandia's Multifuel Combustor allows simulation of combustion conditions in a commercial furnace or boiler. It can be used to test a wide variety of fuels, such as natural gas, oil, pulverized coal and solid or liquid biomass.

This work performed at Sandia National Laboratories is supported by the U.S. Department of Energy under contract DE-AC04-94AL85000.

A Note on Acronyms

In an effort to make this document easy to read, acronyms are generally avoided. When unfamiliar acronyms must be used, they are explained in the proximate text. Acronyms that occur freely in popular or news publications—acronyms such as DOE, DoD, EPA, and NASA—occur in the document without explanation.

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President's Message

Sandia began a new era on Oct. 1, 1993, when Martin Marietta Corp. took over management of the Labs from AT&T, the company that had managed Sandia for more than 40 years. Like AT&T, Martin will continue to meet the challenge issued by President Truman in 1949 to provide "exceptional service in the national interest." Under Martin's leadership, Sandia will continue to go beyond the call of duty in fulfilling its mission as a multiprogram laboratory of the Department of Energy.

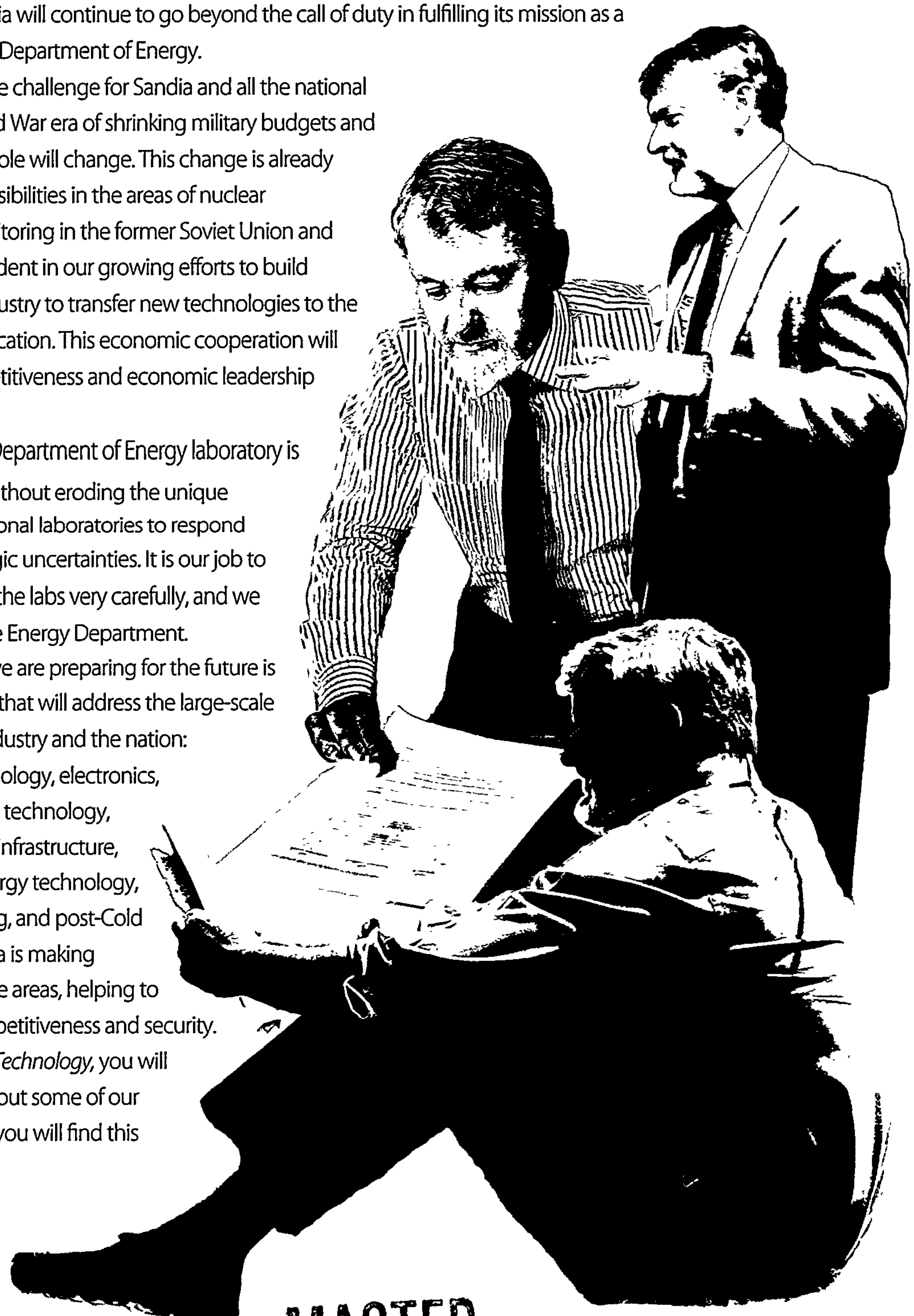
The future holds a formidable challenge for Sandia and all the national laboratories. In today's post-Cold War era of shrinking military budgets and nuclear disarmament, Sandia's role will change. This change is already evident in our increased responsibilities in the areas of nuclear dismantlement and treaty monitoring in the former Soviet Union and elsewhere. The future is also evident in our growing efforts to build partnerships with American industry to transfer new technologies to the private sector for peaceful application. This economic cooperation will help maintain America's competitiveness and economic leadership around the world.

The challenge we face as a Department of Energy laboratory is to implement these changes without eroding the unique capabilities that enable the national laboratories to respond quickly and effectively to strategic uncertainties. It is our job to plan and manage the future of the labs very carefully, and we share this responsibility with the Energy Department.

At Sandia, one of the ways we are preparing for the future is by pursuing strategic initiatives that will address the large-scale technology problems facing industry and the nation: advanced manufacturing technology, electronics, information and computational technology, transportation technology and infrastructure, environmental technology, energy technology, biomedical systems engineering, and post-Cold War defense imperatives. Sandia is making important contributions in these areas, helping to strengthen U.S. economic competitiveness and security.

In this 1994 issue of *Sandia Technology,* you will have an opportunity to read about some of our work in these initiatives. I hope you will find this information timely and useful.

Al Narath



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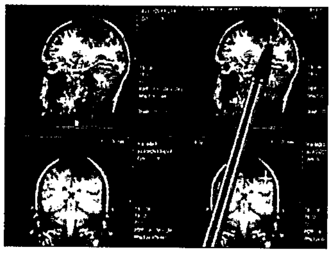
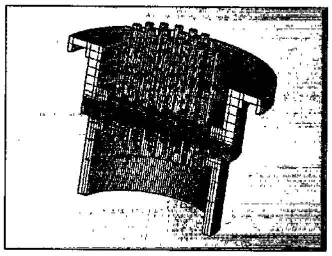
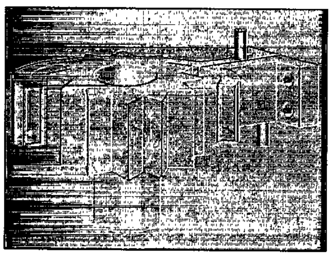


Information & Computation - Sandia aims to help make the Information Age a reality.

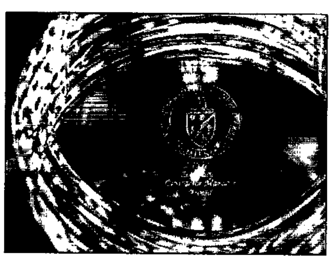


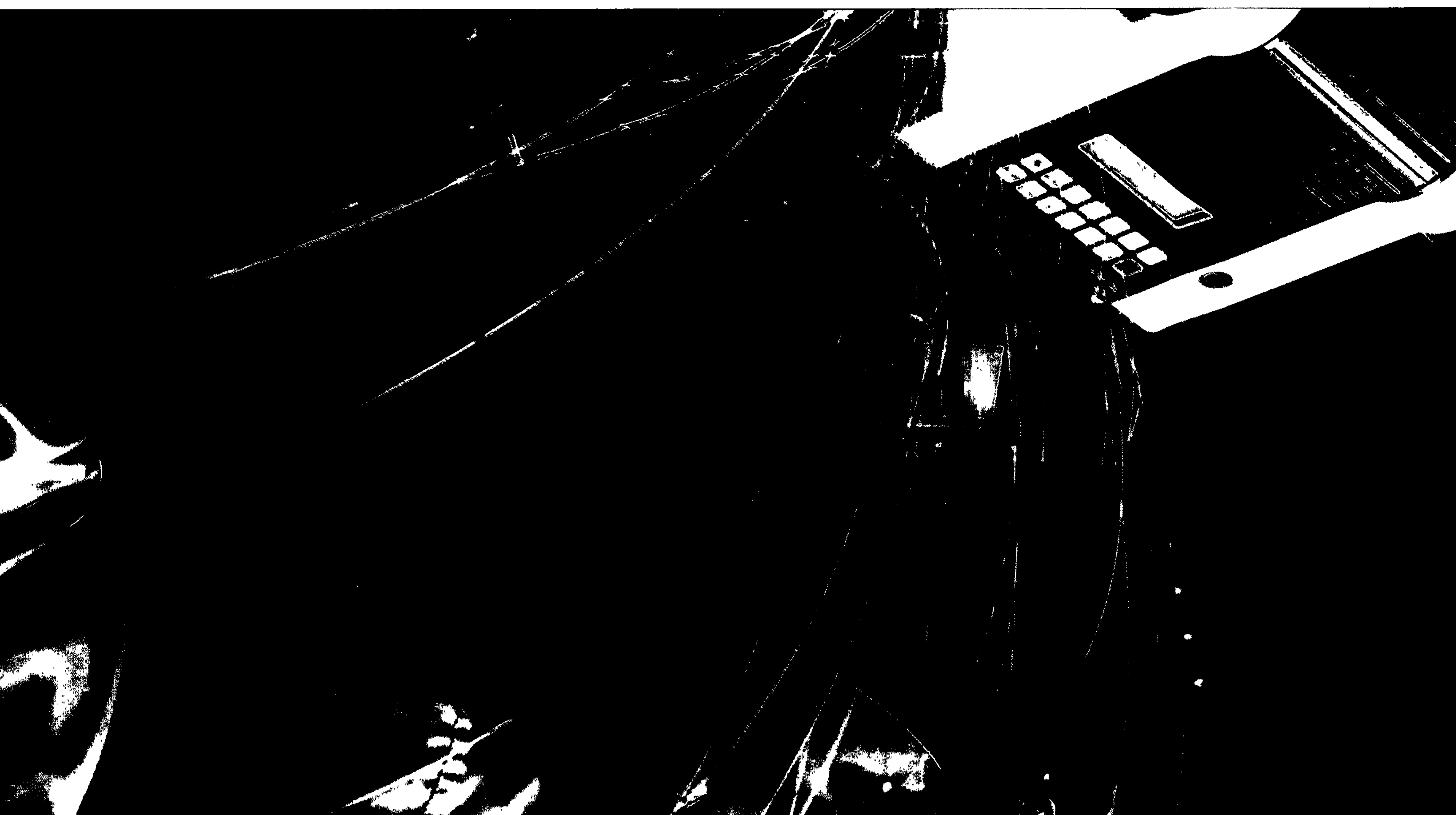
Transportation - This new initiative at the Labs will help improve transportation, safety, efficiency, and economy.



Nonproliferation - Dismantlement and arms control are major areas of emphasis at Sandia.

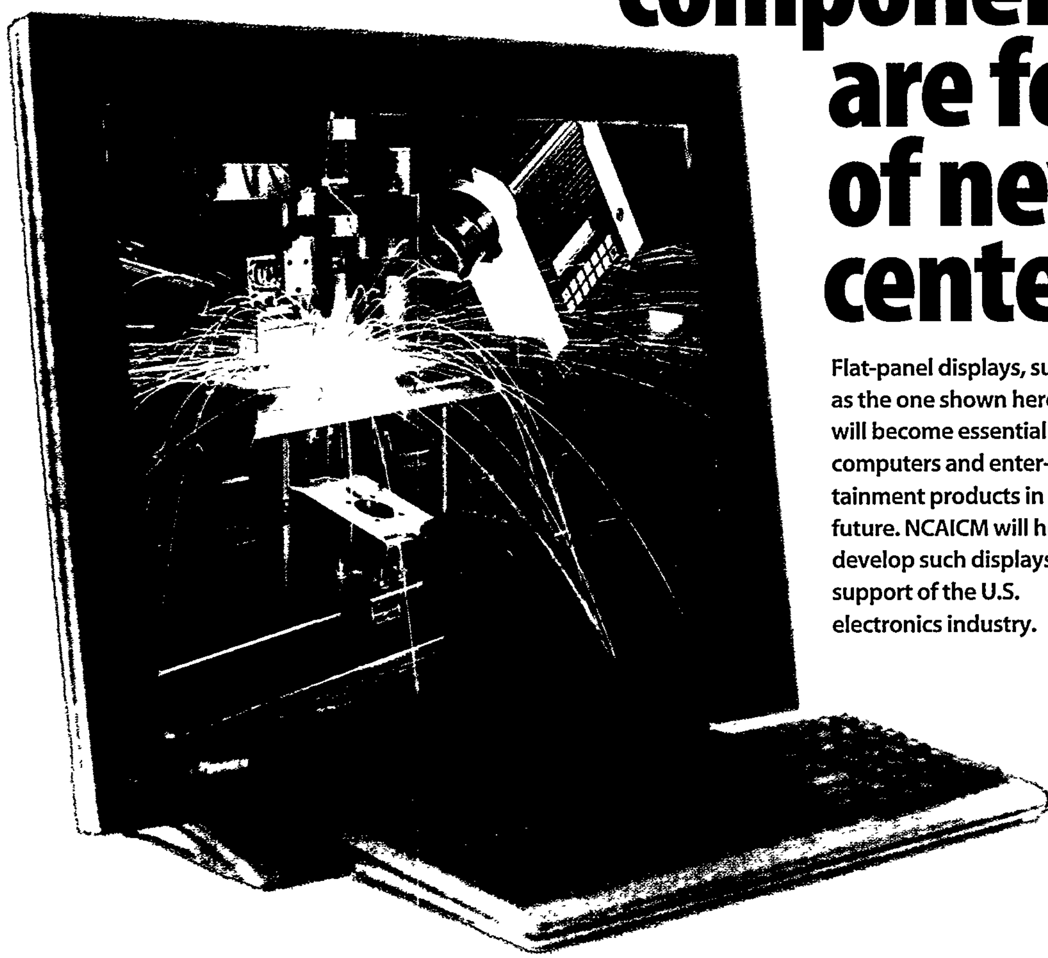
Awards and Patents - Talented, dedicated employees are the backbone of Sandia's success.





ADVANCED MANUFACTURING

Information components are focus of new center



Flat-panel displays, such as the one shown here, will become essential in computers and entertainment products in the future. NCAICM will help develop such displays in support of the U.S. electronics industry.

NCAICM will develop manufacturing tools for electronics plants and processes for making displays and other components

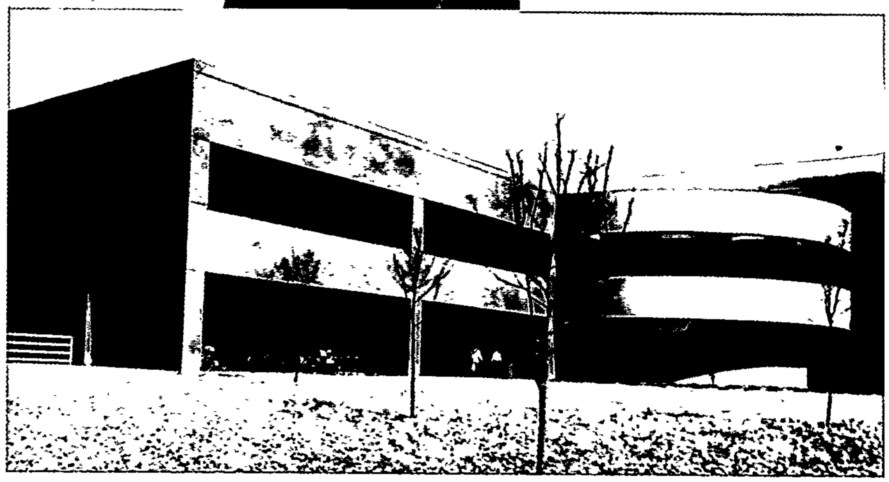
Sandia National Labs, with its history of support for the U.S. microelectronics industry, is home to a new research center for advanced information components. The National Center for Advanced Information Components Manufacturing is concentrating on flat-panel displays and other electronics technologies that will support the U.S. information display industry. NCAICM is particularly focused on information and software tools to guide the development of factories that will produce flat-panel displays and other components.

The Center is a partnership between the Advanced Research Projects Agency and DOE to provide a new avenue for supporting dual-use, commercializable technology at the national laboratories. Display technologies will be essential in both defense applications and commercial products in the coming years, and it could be critical to national security to have an industrial base for such technology within the U.S. Furthermore, displays and other information components are an important part of the electronics industry generally, and NCAICM can help U.S. manufacturers get a leg up on overseas competition.

Jim Jorgensen, NCAICM Director, is excited about NCAICM's work in factory modeling. As he says, "U.S. industry has figured out that modeling factories in software is very helpful, and we believe that modeling, say, the flat-panel display factory will be one of the most useful things we can do for the information components industry."

One of the first steps in modeling a factory is to define the parameters (production rates, energy consumption, labor requirements, etc.) for the manufacturing equipment and build a software model for such machines. The next step is to put several models for manufacturing equipment together as a proposed plant and look at the economics of building and running such a plant. Jorgensen feels that these steps are within NCAICM's reach as the program gets under way. "An economic model of a flat-panel factory would be a great tool to help businesses go to banks and other financial backers and present a realistic picture of what they need to get started. The model would provide a firmer basis for business planning and help U.S. companies survive and grow in a very competitive market." The model could also be the basis for further software developments, such as a computer-generated plant that models actual production and can change the relationships between elements of the plant to improve production management.

NCAICM has received $60 million in funding from ARPA to operate through FY95. Of that amount, about $48 million is available to support proposals from teams of laboratories, industry, and universities for projects supporting NCAICM's goals. Several projects are already under way, and proposals are in the final stages of selection for projects in display technologies, microelectronics, and software modeling. This is a critical time for the display industry, and NCAICM hopes to provide the right base of technology and software to keep U.S. industry competitive in a major world market.



Left—An operator observes a robotic arm loading wafers into a vertical thermal reactor. Below—Office and light laboratory area of Microelectronics Development Laboratory. With the heavy laboratory area, the MDL provides a complete wafer-processing facility.

For more information, call
Jim Jorgensen
NCAICM
(505) 844-1023

Booming business

Electric igniter can inflate air bags or excavate rock

Big John, the legendary miner of song who saved his buddies' lives by holding up a collapsing beam, might not have been buried 600 feet under if mining had been done then like it is today.

In the old days, a miner would step back from an explosive, light a fuze, and duck to avoid flying debris. Later, electrically fired blasting caps attached to long cables became the norm. Nowadays, not only mining, but automobile air bag inflation, explosive bolts, oil well drilling, special effects, satellite deployment, and building demolition can be accomplished with an electric igniter developed at Sandia. Also known as a semiconductor bridge, the device sits on a microelectronic chip smaller than the letters on a penny. The SCB is quicker, more reliable, more precise, and safer than conventional hot wires used to set off explosives.

The SCB was invented at Sandia, and marketing studies done by graduate business students at the University of New Mexico concluded that the product had profit potential. The students made it the focus of an entrepreneurial course; ultimately, UNM's Technology Innovation Center and Sandia's Technology Transfer Department helped form SCB Technologies Inc., a company whose principal stockholders are UNM and New Mexico Tech. SCB then licensed the technology to Thiokol Corp. in Maryland for use in rock blasting, mining, and vehicle airbags and is negotiating more applications with other firms.

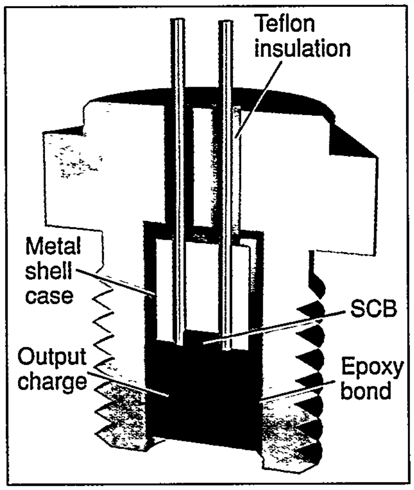
So how might the small and humble SCB have saved Big John? Through greater accuracy and less vibration.

"The primary advantage of SCB is precision timing. Precisely timed explosions result in less ground shock, which means fewer complaints from surrounding communities. The shock waves can be phased to cancel each other and minimize ground tremor," says Sandia scientist Bob Bickes, who invented the SCB with now retired Sandian Al Schwarz about 10 years ago. Since then, many research groups at Sandia have continued to improve and refine SCBs.

Miners may use several hundred such initiation devices at once. If the detonations are timed to go off at just the right moment in several different places, the rock breaks in a predictable pattern—forming, for example, an arch-shaped tunnel through a mountain.

Precisely timed explosions also result in very uniform rubblization—the fragmented rock has fewer oversized particles, making it easier to process and less likely to damage rock-crushing machinery.

This level of precision requires microsecond accuracy. Conventional hot wires ignite explosives within a few milliseconds when they are heated by an



This cross section of a semiconductor bridge device shows the explosive output charge pressed against the polysilicon SCB chip.

electrical current. SCB ignitions take place in microseconds, 1,000 times quicker and therefore more predictable than hot wires.

The SCB is essentially a polysilicon circuit that vaporizes into a plasma—a minute cloud of ionized silicon atoms—when an electric current passes through it. This hot gas has sufficient energy to initiate an explosive by percolating into a powderbed and setting it off. The process requires less than one-tenth the energy needed for conventional hot-wire ignition, and can save medium- to large-scale mining operations hundreds of thousands of dollars a year, estimates Bickes.

But the SCB's use is not limited to explosives. In the case of air bags, for example, entirely different energetic materials are used that do not detonate, but burn rapidly and then ignite a propellant, causing the air bag to inflate.

SCBs can also be combined with sophisticated circuitry, essentially becoming part of a "smart" system. "SCBs can be used to initiate a precisely timed sequence of events," says Bickes, "such as a seatbelt that tightens just before an air bag inflates."

In fact, an SCB can ignite less sensitive materials than those presently used in automobiles. Because they require less energy, they can operate multiple air bags without overtaxing car batteries. SCBs are also resistant to severe environments such as heat and vibration that an air bag must typically withstand.

For more information, call
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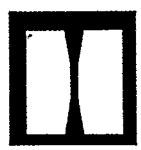
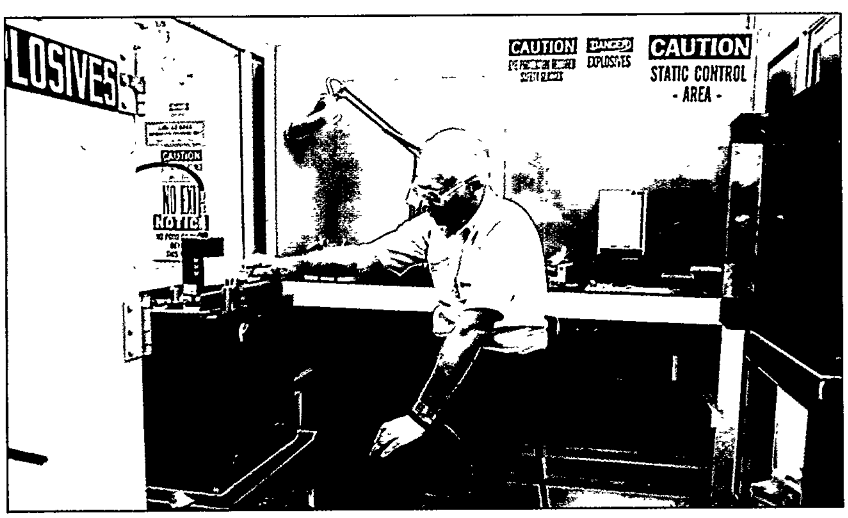
Explosive Components
(505) 844-0423



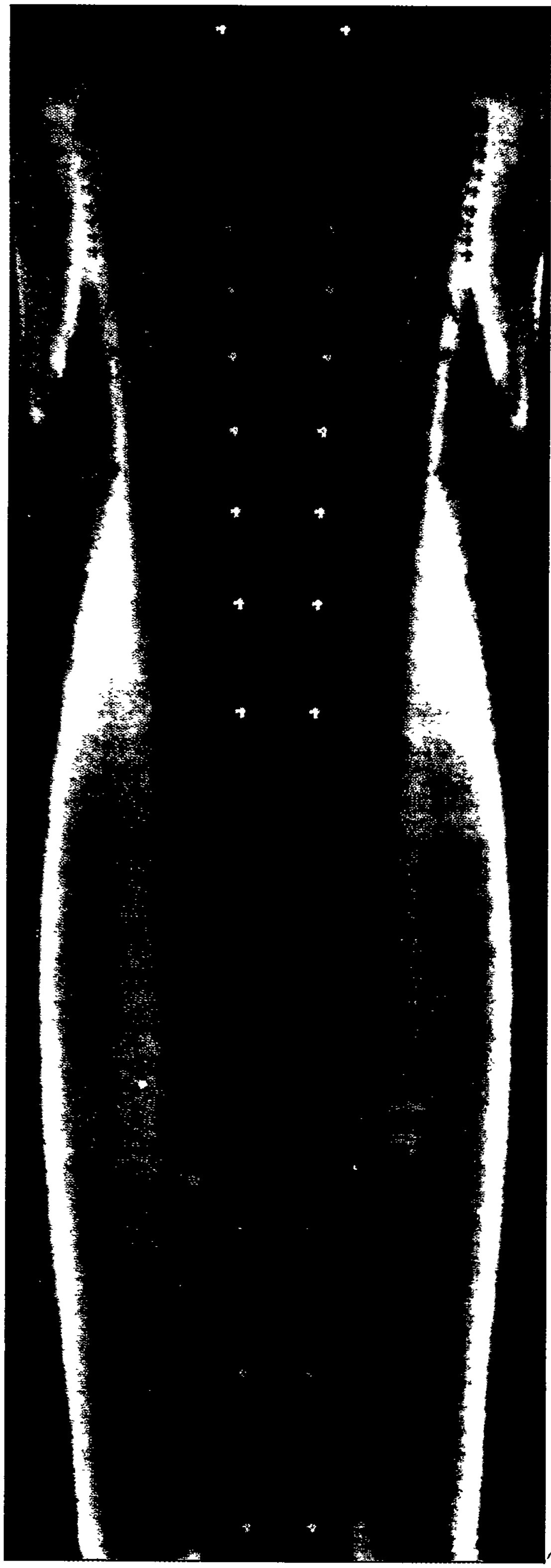
The microelectronic chip that holds Sandia's semiconductor bridge is smaller than the letters on a penny.



Scientist Bob Bickes, coinventor of the semiconductor bridge, checks the performance of one of the devices in a special test lab.

Industrial-strength fibers

Sol-gel processes, once used for car mirrors, have many manufacturing applications



In the 1950s, automakers used sol-gel (solution-gelation) processes to protect rear-view mirrors for automobiles. The mirror base was dipped in a liquid containing a colloidal suspension of titanium dioxide particles—the sol-gel. When the mirror was removed from the liquid, it was dried and baked, leaving behind a thin, reflective layer on the mirror as the solvent evaporated.

Today, advanced materials research at Sandia is expanding sol-gel technology to improve the performance of such diverse items as antireflective and antiscratch coatings, bullet-resistant textiles, lightweight and high-strength metal matrix composites for engine parts, biological and chemical sensors, and even microfilters for water or wine.

Computer modeling at Sandia is improving the understanding of the physics of sol-gel processes. Sandia researchers have long used computer modeling to design protective coatings for weapons and antireflective coatings for solar energy collectors. Their research has led to sophisticated models that have a variety of potential industrial applications. This expertise is available to industry to help optimize and control coating processes, such as simulating the physics of dip coating in sol-gels for making sensors, membranes, and coatings, or simulating the extrusion and drying of individual sol-gel fibers.

"Modeling sol-gel film and fiber formation processes has led to unique and exciting challenges in numerical computation," says Sandia researcher Randy Schunk. "Meeting these challenges has opened up many new opportunities in the simulation of manufacturing processes."

For example, 3M, a leading manufacturer of special materials, is utilizing Sandia's computer model predictions to aid in the spinning of inorganic fibers from sol-gel to reinforce metals such as aluminum or titanium. These metal matrix composites can be used to produce strong, lightweight parts for aircraft, bicycle frames, or cars.

This computer model of flow instabilities in a sol-gel fiber drying tower shows temperature gradations from warm (red) to cool (blue). Such models can be used by industry to optimize coating processes and minimize fiber breakage by controlling parameters such as air flow, heat transfer, and water evaporation.

To produce the fibers, 3M extrudes a sol-gel through tiny holes into a drying tower. As the fibers fall in the tower, moist, heated air is blown in to help evaporate the excess liquid, leaving behind the thin but very tough sol-gel fibers. The computer models help identify tower operating conditions that optimize fiber properties and minimize fiber tangling and breaking by predicting the parameters, such as air flow, heat transfer, and the evaporation rate of water, needed to produce a particular kind of fiber from a sol-gel, notes researcher Greg Evans, at Sandia's California facility.

Materials made by sol-gel processing can have a variety of properties, depending on how they are deposited and treated. If allowed time to react, sol-gel particulates may agglomerate—become denser and form branched, long-chain polymers. The porosity of the polymers is thus directly controlled by the speed of the reaction and drying. If the sol-gel is heated, the polymer chains form a hard, glassy film useful as a surface protectant or antireflectant.

Using computer models, manufacturers can tailor sol-gels to have specific microstructural properties, such as a certain density, pore size, thickness, or surface area. Sol-gels can be used to make industrial filters or sensors with molecular voids of just the right size to detect or capture specific pollutants in air or water.

Sol-gel processes are often more cost-effective and environmentally benign than more conventional methods of producing lightweight, strong composites, such as chemical vapor deposition, evaporation, or spraying. Solvents in the sol-gel process can be recovered and recycled, and sol-gels can be used to treat many kinds of surfaces or to produce stand-alone fibers.

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MICROELECTRONICS

the 1st practical visible microlaser

Revolutionary laser-on-a-chip has host of new applications

1993
- Continuous-wave, electrically excited visible VCSEL
  Schneider et al.
- Electrically excited, pulsed visible VCSEL
  Lott and Schneider

1992
- Mirror and process improvements (infrared VCSEL)
  Lear and Chalmers

1991
- Visible VCSEL
  Schneider et al.

1989
- Electrically excited, pulsed VCSEL arrays
  Jewell, AT&T Bell Labs

1986
- Room-temperature epitaxial VCSEL
  Gourley and Drummond

1979
- First VCSEL
  Iga, Japan

VCSEL development Sandia (right side) and others (left side). As the timeline shows, Sandia has been a primary contributor to VCSEL research and development. Background color corresponds to the part of the spectrum in which VCSELs have emitted visible light.

For more information, call
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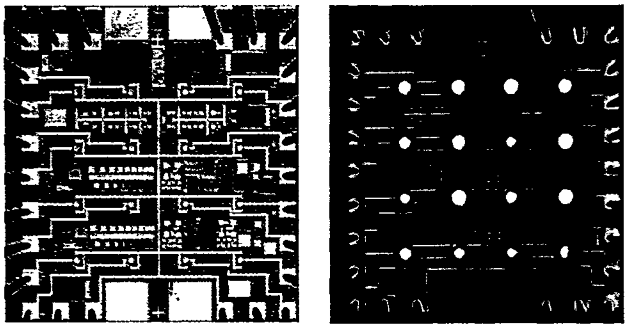
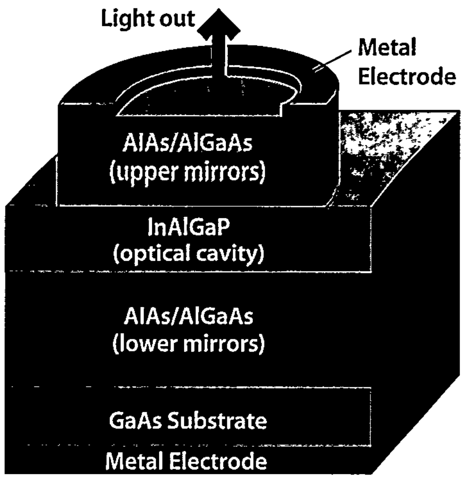
(505) 844-5481

Richard Schneider
Semiconductor Materials
(505) 844-0668



A 4-by-4 array of visible-light-emitting vertical cavity surface-emitting lasers (VCSELs) before and after being electrically pulsed. Since development of this array, Sandia scientists have developed a VCSEL that emits a continuous wave when a constant current is applied.



The VCSEL: How it's made, what it looks like, how it works

The VCSEL is built by sequentially layering many different semiconductor materials using growth techniques such as molecular beam epitaxy or metallorganic vapor-phase epitaxy. This process "spray paints" beams of atoms on a semiconductor substrate. By mixing and matching these layers, crystals can be precisely built to optimize electrical and optical properties.

The resulting structure resembles the inside of a sandwich: the center layer is a light-emitting optical cavity; the surrounding layers are aluminum-arsenide/aluminum-gallium-arsenide mirrors. The optical cavity region consists of layers composed of combinations of indium, gallium, aluminum, and phosphorus. Electrical charges approaching from the mirror layers above and below get trapped and recombine in this cavity to emit red light. The mirrors reflect the emitted light, which is amplified in the central layer, to produce the laser beam.

Imagine the following machines in the office of the future: A digital visual projection display system that fits in the palm of the hand. An inexpensive, high-resolution color laser printer. Speed-of-light optical computer components that don't heat up. Smaller, cheaper bar code scanners.

These and other revolutionary laser-based applications will soon be possible with the help of a tiny microlaser, developed at Sandia and sponsored by the Energy Department's Core Competency Program.

Called a vertical cavity surface-emitting laser (VCSEL, pronounced "vixel"), this tiny laser emits a steady, concentrated, visible beam of 660- to 680-nanometer-wavelength light from an aperture 5 to 50 micrometers in diameter—between one-twentieth and one-half the thickness of a strand of human hair. This is the world's first VCSEL that can emit continuous visible light when turned on at room temperature by constant electrical current. The new VCSEL "is ideal for the many applications where focusing to a small spot or coupling to an optical fiber is needed," reports the August 1993 issue of *Physics World.*

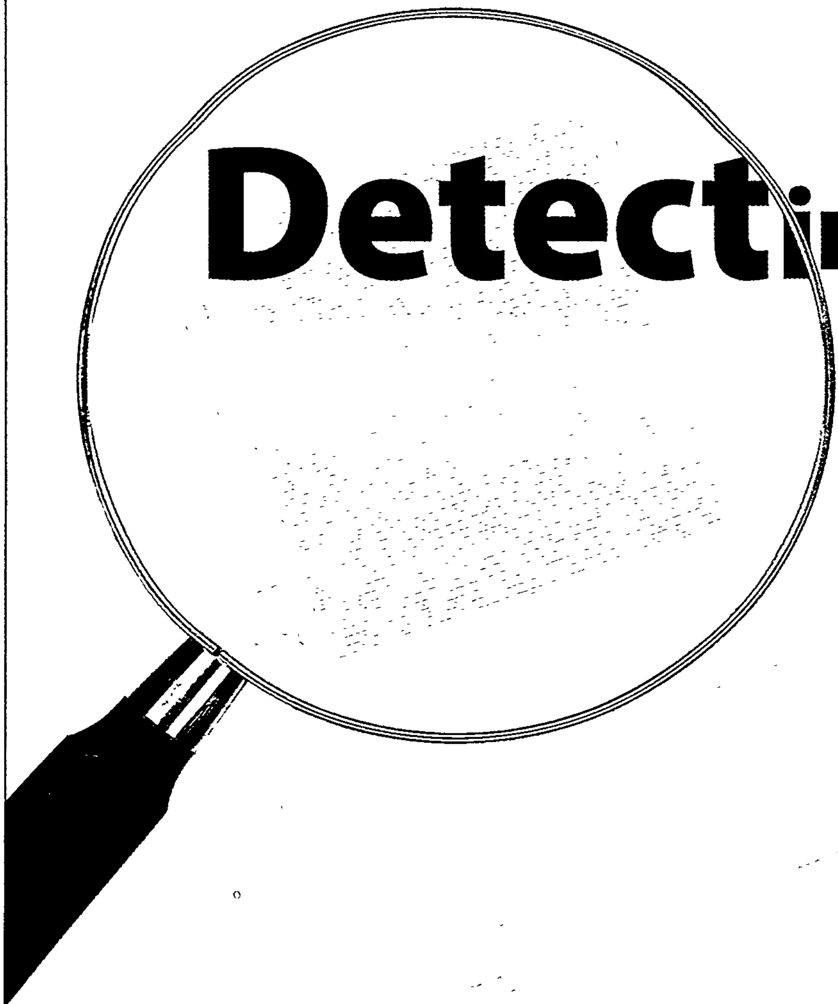
Because the electrically driven VCSEL can be manufactured in closely packed arrays, some observers believe it will have the same effect on computer and communication technologies that the transistor had in the early 1960s. Today the laser of choice for compact-disc players, laser printers, and fiber-optic communications is the edge-emitting semiconductor laser, which emits light sideways from the edge of the semiconductor chip. The VCSEL is not only several hundred times smaller, it emits light perpendicular to the chip's surface. This feature makes it easy to fashion closely packed arrays of lasers the way integrated circuit technology made it possible to fit thousands of transistors on a tiny chip, and also enables economical wafer-level testing.

"It should be possible to put more than 10,000 of these devices on a single two-inch wafer," notes Sandia researcher Rick Schneider. As an added advantage, the VCSEL does not require the expensive beam-focusing optics necessary for edge-emitting lasers.

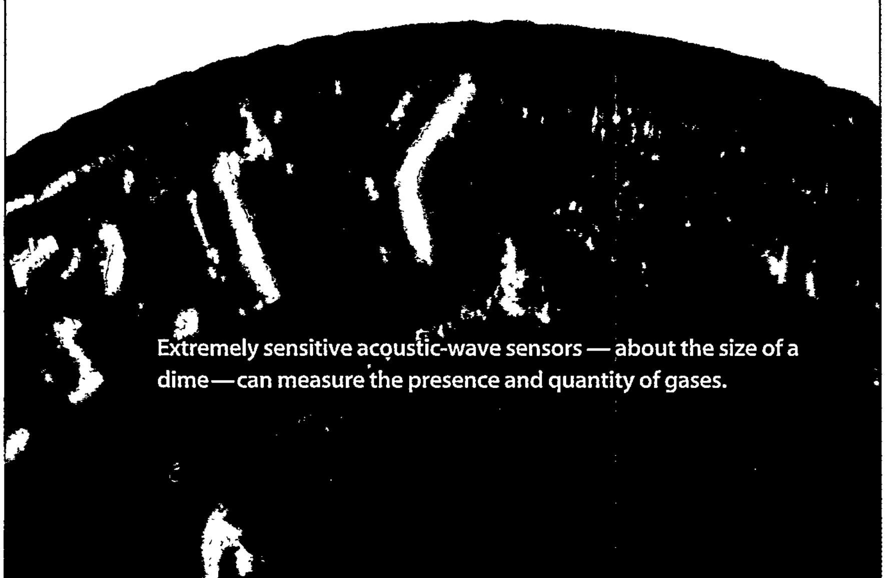
The visible-light VCSEL is the outgrowth of years of research. Following demonstration of the VCSEL concept by researchers at the Tokyo Institute of Technology in 1979, Sandia researchers Paul Gourley and Tim Drummond developed the first room-temperature, optically pumped VCSEL in 1986. After AT&T inventor Jack Jewell designed the first electrically driven VCSEL array in 1989, Rick Schneider and others developed the first VCSEL that emitted visible light in 1991. Since then, Sandia has continued to improve the VCSEL, increasing its electrical efficiency and manufacturability.

Sandia's most recent achievement is continuous-wave operation of visible-light VCSELs at room temperature. "This means the device can be operated without cooling, and from a direct current source, eliminating the need for expensive current pulse generation electronics," notes Jim Lott, an Air Force officer and student at the University of New Mexico who helped develop the new VCSEL while on assignment at Sandia. "These developments have captured the interest of many major optoelectronics companies," observes Schneider. Sandia is now exploring working agreements with several manufacturers to develop VCSEL applications.

Detecting chemical emissions



Tiny quartz microsensor identifies airborne pollutants



Extremely sensitive acoustic-wave sensors — about the size of a dime — can measure the presence and quantity of gases.

Quartz, a rock-forming mineral made of silicon dioxide, the most abundant and widespread of all minerals, is used in a variety of modern electronic devices, from radios to wristwatches. As early as World War I, it was used to detect submarines. Today, Sandia is developing quartz microsensors that can detect a broad range of chemical pollutants and hazardous wastes, such as trichloroethylene, carbon tetrachloride, benzene, hexane, and toluene — in the air, in water, or in waste streams.

These applications are possible because of a property known as piezoelectricity — when a crystal is subjected to a voltage, it physically deforms. Quartz — silicon dioxide in crystalline form — is particularly versatile because when a quartz crystal is cut into a waferlike shape, it can be made to vibrate when subjected to a high-frequency, alternating voltage.

These quartz resonators are also highly sensitive to changes in mechanical properties of thin films deposited on the surface, such as the stiffness and mass of the films. When these variables change, the vibrations also change.

In developing the quartz microsensor for industrial pollutants, Sandia researchers designed a surface acoustic-wave device much like those used to process signals when a television viewer switches channels. To fabricate the device, they deposited tiny, interdigitated fingers of gold on the surface of a quartz substrate. These gold electrodes conduct electricity, causing the quartz to vibrate and generate surface acoustic waves, or SAWs, explains Jamie Wiczer, manager of Sandia's Microsensor Research and Development Department.

Surface acoustic waves are similar to Rayleigh waves in an earthquake; they propagate only on the surface, not through the bulk of a material. On a quartz wafer, their peak amplitude may be on the order of 10 nanometers—10 billionths of a meter. But because of the acute sensitivity of the quartz device, a change in weight amounting to only nanograms (billionths of a gram) is enough to change the perturbations in the surface acoustic waves.

The individual microsensors, which are actually small pieces of crystalline quartz coated with special films, are connected to microcircuits that can be attached to a laptop computer and plugged into the cigarette lighter of a car. These features make the sensor system very portable for working in the field—for example, to detect chemical emissions at a waste site or a manufacturing plant.

Sandia recently tested the quartz microsensors at AlliedSignal Kansas City to monitor emissions from solvent-spraying operations used to clean printed circuit boards, says chemical engineer and project leader Greg Frye. The work was sponsored by Sandia's Environmentally Conscious Manufacturing program, a high-priority effort of the Department of Energy. Sandia researchers detected trichloroethylene emitted into the atmosphere on the order of 2,000 parts per million.

Chemists then recommended switching to d-limonene, a much safer substitute for TCE. Workers who use spray guns to clean the circuit boards also began using laptop computers to get constant readings of TCE emissions. They soon discovered that they could control emissions to a large degree based on how they pointed the spray gun and how they mixed air and solvent in the gun.

In the end, the Sandia-AlliedSignal team reduced emissions from 2,000 ppm to 40-50 ppm, a factor of 40 reduction.

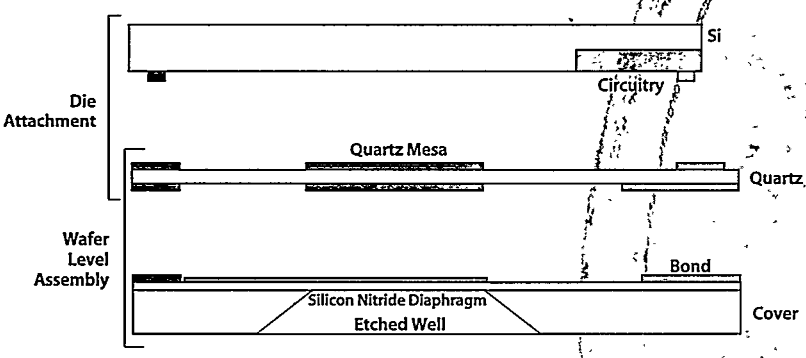
The acoustic sensor is one of several classes of microsensors developed at Sandia. A semiconducting silicon sensor designed at Sandia detects hydrogen and other gases, and has been tested for use on NASA's space shuttle fueling system. A fiber-optic sensor to measure martian soil properties has been developed in a joint Sandia-Jet Propulsion Laboratory program and will be on board a U.S.-Russian Mars probe to be launched from Russia in October 1994.

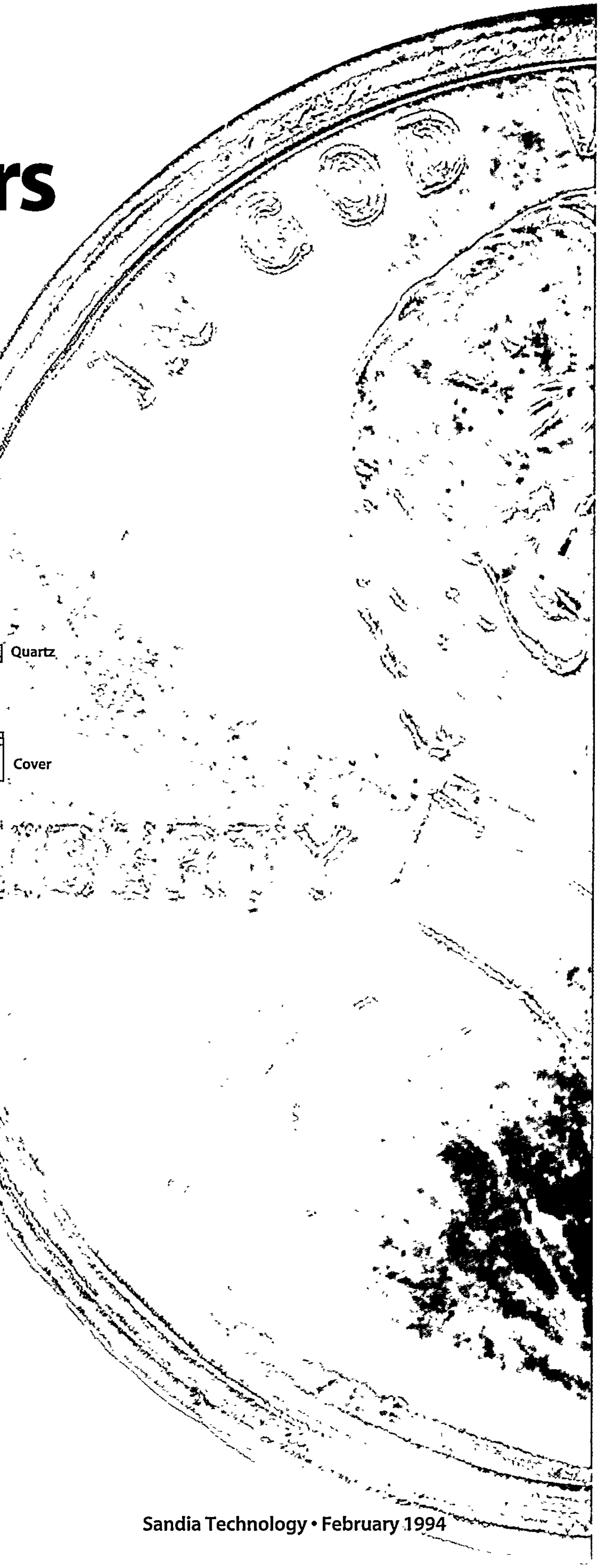
For more information, call
James Wiczer
Microsensor Research & Development
(505) 844-5672

Greg Frye prepares to install a portable acoustic-wave sensor that measures volatile organic compounds in monitoring wells below the surface.

Quartz, silicon, and microsensors

Combined technologies open new fields for miniature sensors





Before atomic clocks were developed, long before quartz watches became common, the most accurate time was kept by quartz chronometers. Quartz is a piezoelectric material: a voltage applied to a quartz element will cause mechanical changes, including very steady vibration that can be translated into accurate time. However, this vibration can change in response to other environmental factors, such as temperature, pressure, and applied mass, and this sensitivity suggests many applications for quartz sensors.

A Sandia research group that was originally involved in timing activities has recently begun applying quartz resonators to new fields. By literally joining miniature quartz resonators to silicon microcircuitry, they have created new devices that can monitor body functions; sense extremely small temperature, pressure, and acceleration changes; and detect very small concentrations of chemicals.

Dale Koehler, of Sandia's Resonator, Oscillator, and Medical Applications Department, is excited about the potential for widespread use of quartz sensors. "The crystal elements of quartz watches, with tuning fork structures for keeping time, cost about eight cents each. The high reliability of quartz sensors, with potential low cost, could lead to dozens of applications," Koehler believes. Part of the superiority of quartz devices comes from the fact that quartz responds to environmental changes with changes in its vibration rate, and measurement of vibration rates is a very well-developed technology.

Several applications for miniature quartz sensors are under development right now. One area of interest is biomedical engineering, and the application is a radio beacon, smaller than an aspirin, that can be ingested by a patient. The device can sense internal functions, such as temperature and pressure, and can be monitored externally. One advantage the device provides is the capability to take many measurements over a long period of time.

Sandians are also working with an industrial manufacturer on microminiature devices that could be installed in retail products. Such devices could provide positive product identification and monitor temperature, pressure, and other operating conditions.

In all such applications, the operating principles are the same. A tiny power source is connected to a quartz resonator to provide a stimulus that causes vibration. The rate of vibration (frequency) is controlled by physical attributes of the quartz element, such as its dimensions and crystallography (orientation of the crystals). A microelectronic device (essentially, an integrated-circuit silicon chip) is mounted on the quartz, and changes in the vibration rate of the quartz element are translated into digital data on the chip.

Research into miniature quartz sensors is supported by DOE's Defense Programs. These new sensors have significant potential for monitoring many qualities much more cheaply, reliably, and unobtrusively than is now possible. In areas such as transportation, biomedicine, and environmental research, quartz sensors, monitors, and transmitters will allow data collection in locations that are inaccessible, or nearly so, at this time.

For more information, call
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Resonator, Oscillator, and Medical Applications
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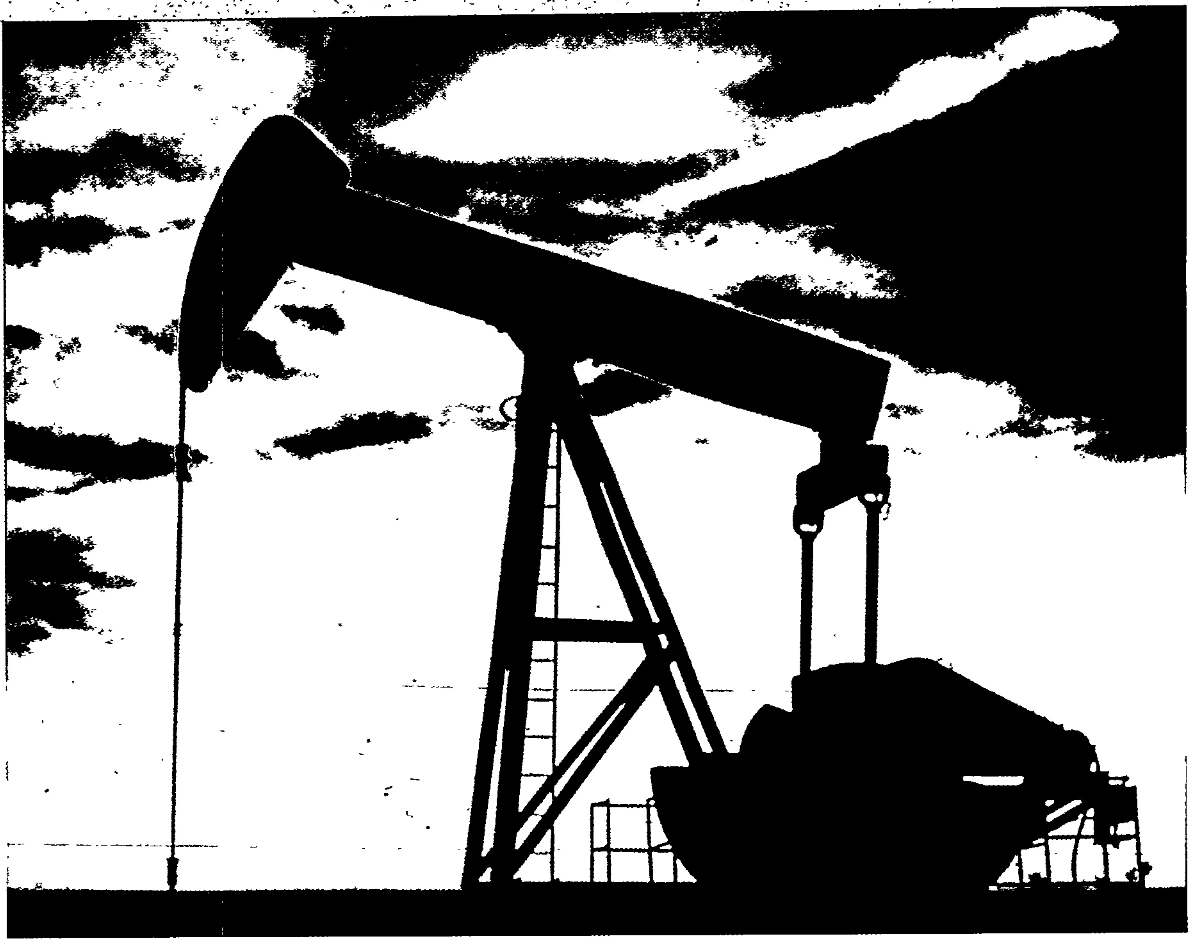
ENERGY



Computer model predicts cleanup of wax in wells

Sustaining domestic oil production

Many of the fuels we use—gasoline, natural gas, propane, butane, diesel fuel, automotive oil, even paraffin in candle wax—are petroleum by-products.

Unfortunately, paraffin, or wax, can be a problem in about one-third of all oil wells in the U.S., where it is dissolved in underground oil deposits. As the oil nears the surface, it cools and the paraffin solidifies. Eventually, the solidified paraffin can clog the well and the pumping machinery. This increases operating costs and is especially bothersome in stripper wells that produce fewer than 10 barrels per day.

Traditionally, oil producers have tried to solve the problem by pumping hot oil or hot water into the well casing to melt the paraffin, potentially causing it to flow back down the well. However, new research conducted by scientists at Sandia and Petrolite, a chemical company, shows that this practice, known as hot oiling, may not always be effective. In fact, because this technique forces more paraffin back into the rock, the paraffin may accumulate and damage the oil-bearing formation.

Based on this research, the Sandia-industry team has developed a list of good practices and special software to help oil producers choose the best treatment for paraffin buildup. Every oil well is different, says Chip Mansure, of Sandia's Geothermal Research Department.

"We developed a software program, called the 'Hot Oiling Spreadsheet,' which is available to industry free of charge," says Mansure. "The user enters information such as the size of the well (which indicates the amount of steel), and how hot and how fast the hot-oil truck, which heats the oil to be used in

For more information, call
Chip Mansure
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the process, will pump hot oil into the casing. The program then predicts where paraffin will be a problem and whether hot oiling will be effective.

"If hot oiling would not be effective, the producer can look at other means of removing the paraffin, such as using chemicals or mechanical devices."

This work is one of many projects sponsored by the Oil Recovery Technology Partnership, an alliance of the Department of Energy, Sandia and Los Alamos national laboratories, and the petroleum industry. The goal of the partnership is to find cost-effective ways to sustain domestic oil production.

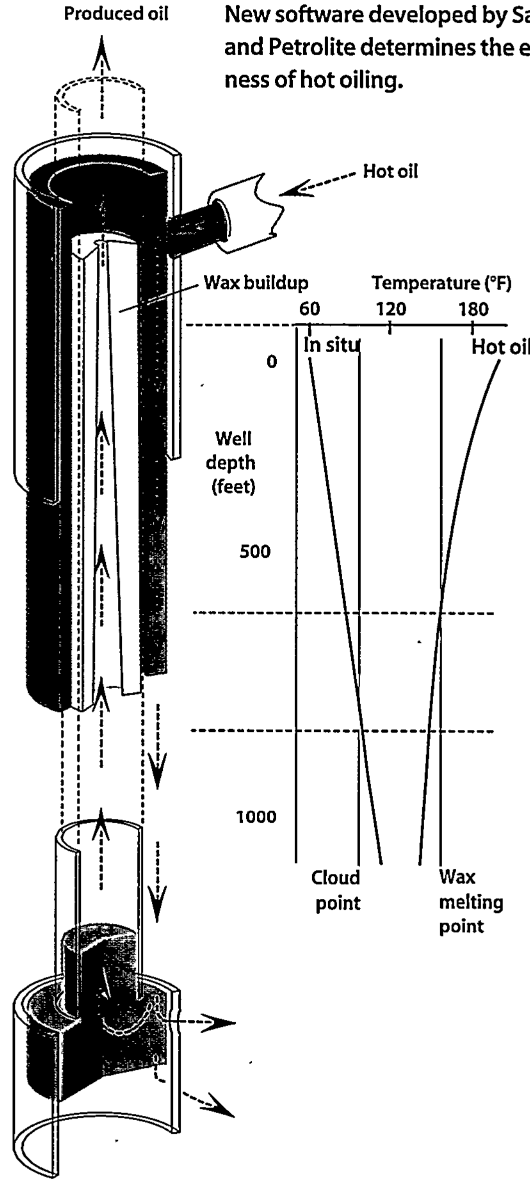
Good practices are designed to avoid the problems associated with hot oiling. For example, in a deep well, the large amount of steel in the well casing draws heat away from the hot oil quickly—so quickly, in fact, that by the time the hot oil reaches the bottom of the well, it's cooler than the oil at the bottom. The most effective hot oil jobs, researchers found, are those that deliver the most heat in the shortest time using the least fluid.

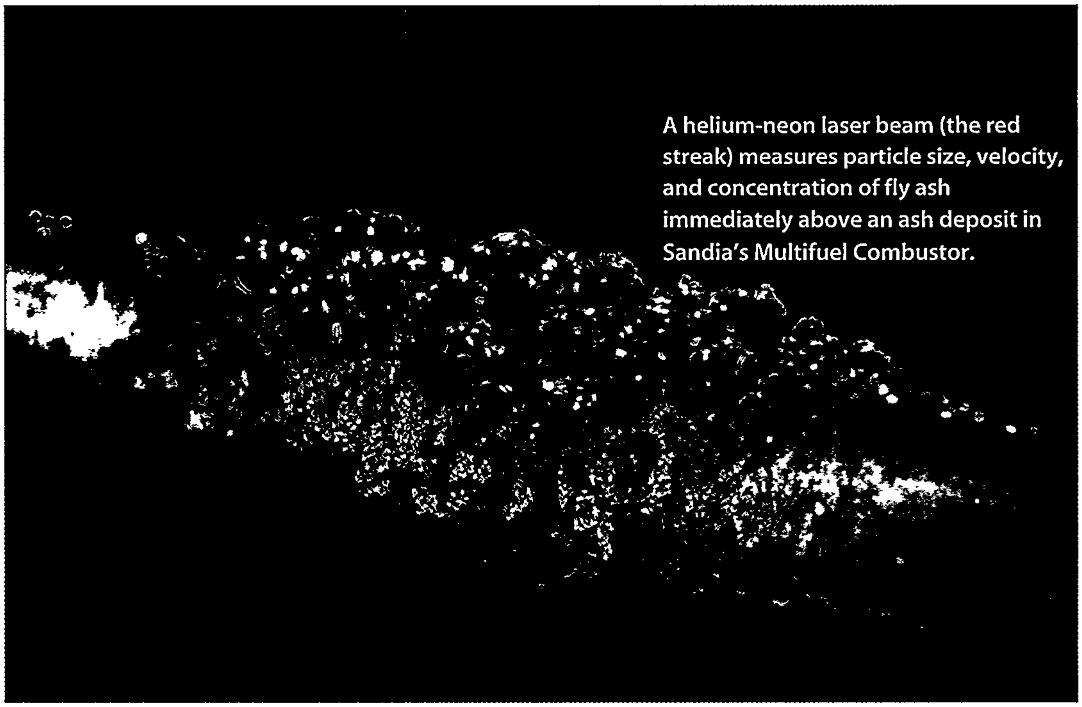
Other good practices include:

- The better the quality of the hot oil, the lower the potential for formation damage.
- The well pump should be operating while the hot oiling takes place—otherwise, the wax may have a chance to resolidify, making it even harder.
- The well pressure should be high enough that the oil in the well does not boil, leaving wax and liquid behind to accumulate.
- The volume of oil injected should be limited because stock-tank oil can contain wax crystals, asphaltenes, scale, and corrosion products that can damage the formation.
- The plunger-lift or piston method of oil extraction, an option for some wells, or mechanical scrapers are alternative methods of removing paraffin if hot oiling is determined to be ineffective.

The spreadsheet was developed based on field tests in Oklahoma, Texas, and New Mexico. The software is compatible with most computers.

Paraffin is estimated to be a problem in about one-third of all U.S. oil wells. New software developed by Sandia and Petrolite determines the effectiveness of hot oiling.





A helium-neon laser beam (the red streak) measures particle size, velocity, and concentration of fly ash immediately above an ash deposit in Sandia's Multifuel Combustor.

Cleaner coal power

Sandia helps solve ash-related problems in coal-fired boilers

Despite the proliferation of new energy technologies, coal is a mainstay for electric power generation. More than half the nation's electricity comes from coal, and the U.S. has approximately 31 percent of the world's known recoverable coal reserves, enough to satisfy domestic electricity needs for at least 200 years.

Improving the way coal is burned to produce electricity is of utmost importance to coal-fired utilities such as the Northern Indiana Public Service Company, which recently worked with Sandia to turn a waste stream into a marketable product, save money, and improve the efficiency of its energy operation.

To meet new federal requirements requiring lower sulfur emissions, Indiana's Mitchell Station electric utility began experimenting in 1989 with western coal, which has a lower sulfur content than eastern coal, as an alternative to expensive desulfurization equipment. But worsening ash deposits and continuing problems with unburned carbon led the utility to seek help from Larry Baxter of Sandia's Combustion Research Facility in California. Baxter conducted research sponsored by the Energy Department and identified process improvements that could yield savings of as much as $1 million a year, estimates Mitchell Station plant manager Larry Nemcek.

Although its sulfur content is lower, not as much heat can be extracted from western coal to drive steam turbines. To compensate, NIPSCO tried blending western and eastern coal. This caused more ash to stick to the walls of the boiler and the boiler heater tubes. "By working with Larry Baxter, we discovered that the tenacity of the ash from a coal blend is higher—particularly in blends that are 60 percent western and 40 percent eastern," recalls plant engineer Larry Dora.

Hard-to-remove ash deposits were a problem in the 10-story-high, coal-fired boilers. Inside the radiative portion of the furnace, where the coal burns, a reflective coating on the ash reduced heat absorption, causing higher temperatures and increased ash formation in the convection region, where heated flue gas flows past tubes filled with steam. If left unchecked, openings between the tubes can clog completely with ash and the boiler must be shut down for cleaning. "Ash coating of coal-fired boilers is a serious problem," observes Baxter. "Experts place its cost at $1 billion to $5 billion a year."

Baxter's predictions that blended coal would make ash removal more difficult were supported by data from Mitchell Station. Baxter and Dora presented the results at the International Joint Power Generation Conference in 1992, where their work was named outstanding paper of the session. Their analysis allowed Mitchell Station engineers to choose the best blend ratio of eastern and western coal.

Another problem in the Mitchell Station boilers was a high unburned carbon content. This not only meant reduced fuel efficiency; it also made the ash impossible to sell as aggregate for concrete, which must have less than 3 percent carbon content. Instead of selling the ash, NIPSCO had to pay for ash disposal.

Sandia's analysis linked the unburned carbon content to the pulverizing process. Because eastern coal is harder than western coal and the two coals are usually blended before being pulverized, eastern coal particles are larger and do not burn as efficiently. Pulverizing the coals separately reduces unburned carbon content.

Baxter continues to work with utilities and fuel suppliers and is using his experience with coal-fired boilers to study ash deposition in biomass combustion.

For more information, call
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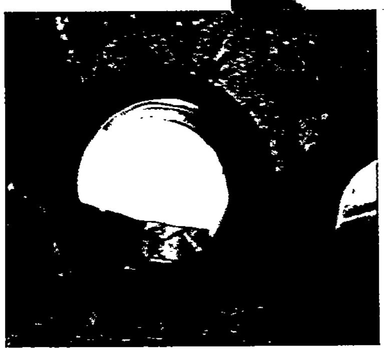
Fuels such as natural gas, oil, pulverized coal, and solid or liquid biomass can be tested in Sandia's Multifuel Combustor. The combustor allows simulation of combustion conditions in a commercial furnace or boiler.

Sandia scientists boil water from inside out and upside *umop*



Containing the 'China Syndrome'

Video cameras show heat sensing arrays attached to the inner vessel (top).

When the inner vessel is heated, it causes the 20,000 gallons of deionized water between the inner and outer vessels to boil (middle).

The inner test vessel is clearly visible through access ports in the outer vessel. These ports allow diagnostic instruments to monitor conditions inside the vessel during a simulated meltdown accident (bottom).

Though extremely unlikely, a meltdown—sometimes called the "China Syndrome," after a popular movie—is clearly the most dangerous potential accident that could occur in a nuclear power plant.

Since its beginnings, the nuclear power industry has created multiple physical barriers to protect against failure. Sandia is now testing one such defense that may prevent even the worst meltdown in a nuclear reactor: the flooded-cavity concept. This concept is based on immersion of the reactor pressure vessel in a water pool. Small-scale experiments indicate that water could potentially extract heat from the core debris during a severe accident. As a result, the surface temperature of the vessel remains very low, not much higher than that of a kitchen oven. This approach is now being considered as an option for accident management in new reactor designs and existing commercial nuclear reactors.

The principle can be compared to using a flame to boil water in a paper cup, according to T.Y. Chu, who leads the Sandia effort to confirm the flooded-cavity concept. "Surprisingly, the cup will stay intact as long as there is water boiling in it," he says. "In the case of a reactor accident, the vessel is saved from the hot molten fuel by water boiling outside the vessel instead of inside."

The boiling process is unique because the heated surface is very large and faces downward. To investigate how boiling is affected by the upside-down geometry, Sandia researchers have built the world's only facility designed to perform reactor-scale testing of the flooded-cavity concept. Called CYBL, or Cylindrical Boiling facility, the test unit resembles a giant double boiler. Quartz lamps are lowered into the inner vessel to simulate the heat from molten nuclear fuel rods, and water fills the space between the outer and inner vessels to provide cooling.

Sandia originally built the $2.5-million CYBL facility under the sponsorship of DOE's New Production Reactor program—a project to produce weapon materials. Despite nuclear arms reductions, the DOE's

Office of Nuclear Energy continues to support CYBL because of interest from the nuclear power industry in the U.S. and other countries, notes Sandia researcher Scott Slezak.

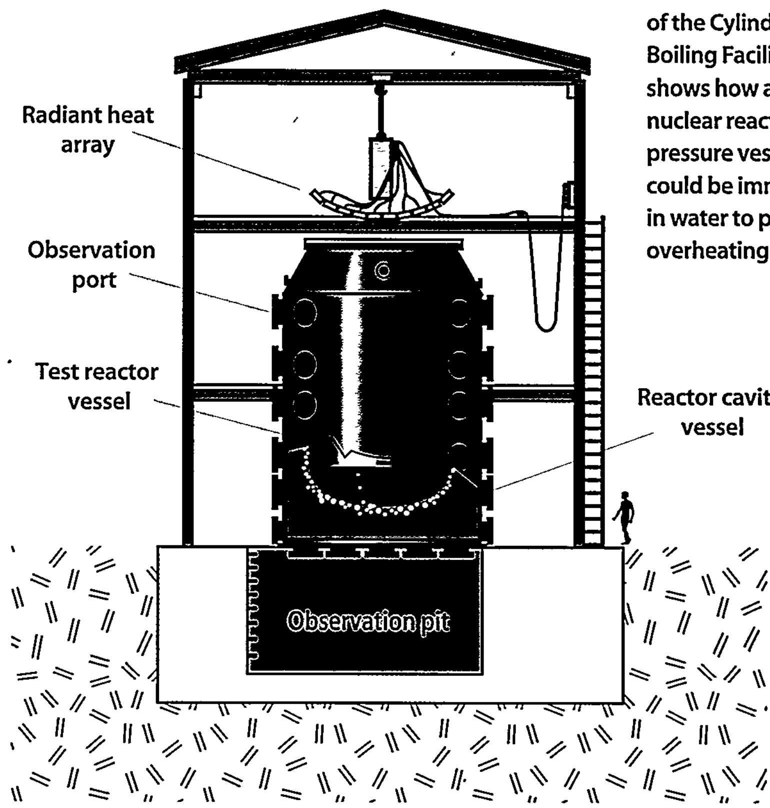
CYBL consists of two stainless steel test tanks weighing approximately 50 tons. The large outer stainless steel vessel simulates a reactor cavity. The smaller stainless steel inner tank simulates the reactor pressure vessel. The entire assembly is housed in a three-story building.

During a simulation, 800 quartz lamps, each able to deliver 6,000 watts of heat, are lowered into the inner vessel to simulate the heat from disintegrated fuel rods. "The maximum energy is 40 watts per square centimeter—roughly 400 times the energy you get from the sun for the same-size surface," explains Keri Sobolik, thermal analyst for CYBL's heat lamp array.

Video cameras record the boiling process through viewing ports in the outer vessel. Hundreds of thermocouples embedded in the vessel measure temperature. A computer system collects the data and produces diagrams of heat flux and temperature.

Boiling passes through stages, or regimes, explains Chu. One of these regimes is film boiling. "In the film boiling regime, so much vapor is accumulated along the outer surface of the inner vessel—effectively forming an insulating layer—that the ability to transfer heat could be compromised and the surface temperature would rise to unacceptable levels," he says.

Tests will help make it possible to confirm the flooded-cavity concept under realistic scales and conditions. During a series of experiments in July 1993, the simulated reactor vessel was kept cool by the boiling water; film boiling did not occur.



This cross-section of the Cylindrical Boiling Facility shows how a nuclear reactor pressure vessel could be immersed in water to prevent overheating.

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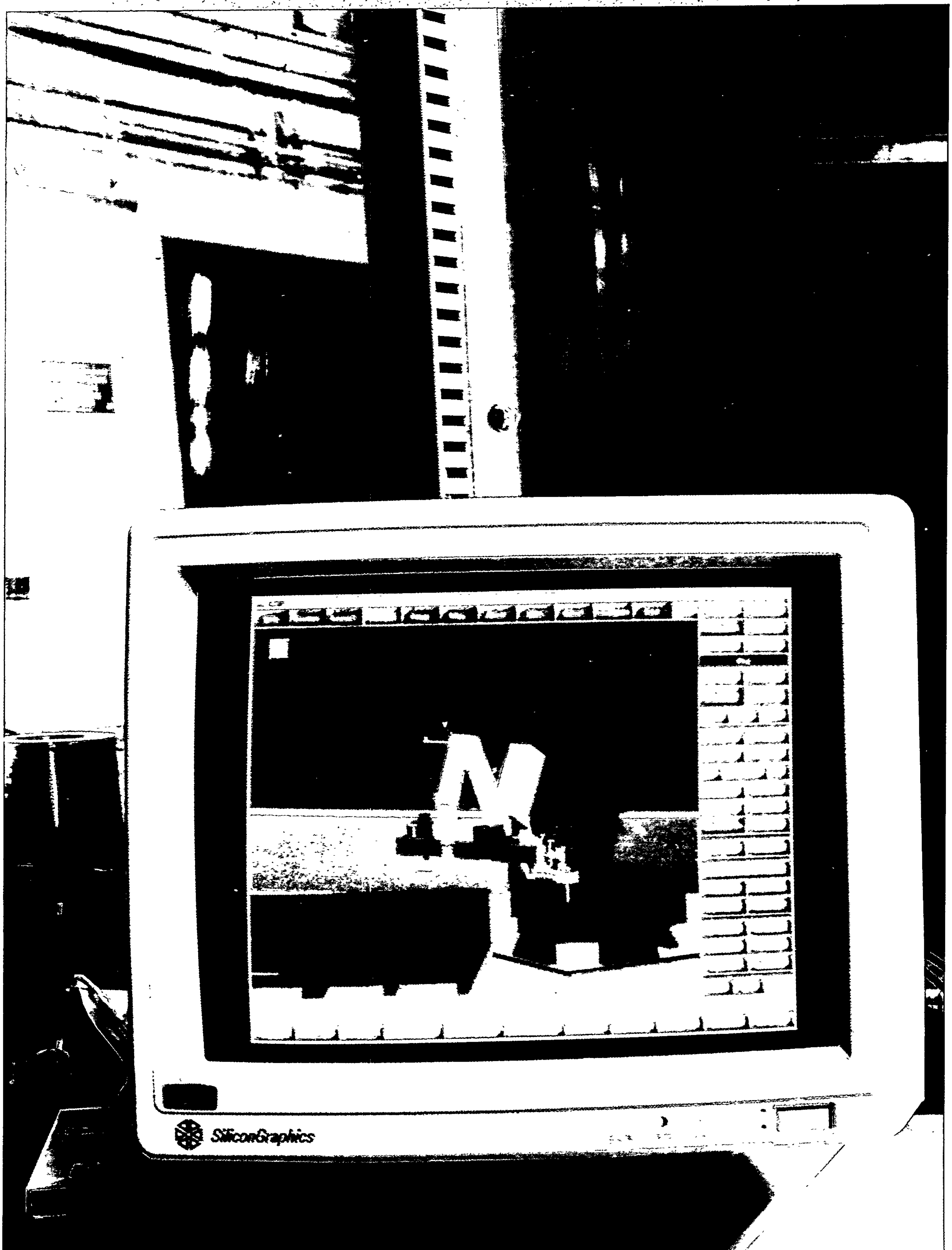
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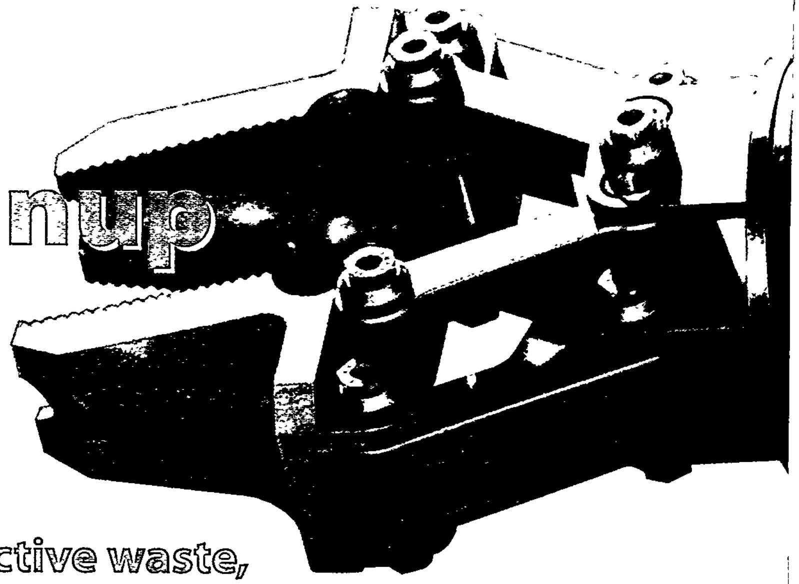
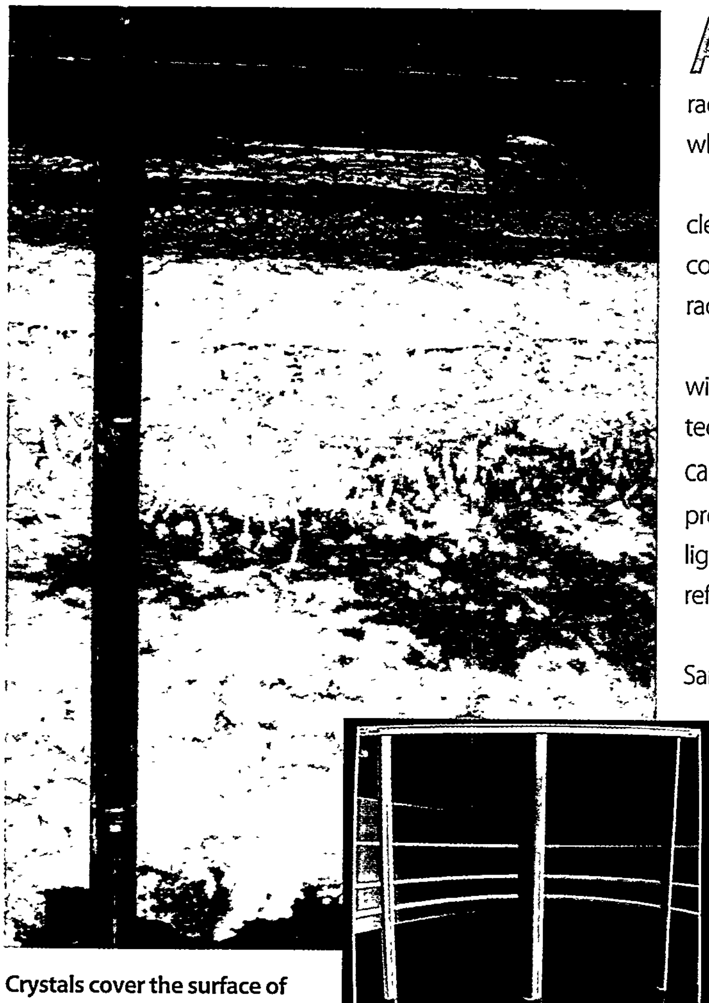
ENVIRONMENT

Robotic cleanup



For humans handling radioactive waste, video control is better than being there



Crystals cover the surface of radioactive sludge in the buried underground tanks (above). A three-dimensional virtual reality simulation (inset) shows a computer-generated model of the interior of a tank. Such models will be used to guide a robot during cleanup.

At the Hanford nuclear research facility near Richland, Washington, buried tanks are slowly leaking radioactive waste. In the near future, robots will go where humans cannot and handle the problem.

Sandia scientists are helping the Energy Department clean up the site by designing robotic systems and data collection techniques that will limit human exposure to radiation.

The project combines the latest in data collection with three-dimensional viewing and remote control technologies. Data are collected through a process called structured lighting, in which a laser mounted on a precision pan-and-tilt unit projects a horizontal plane of light that illuminates the surface of the waste and reflects an image back to a sensor.

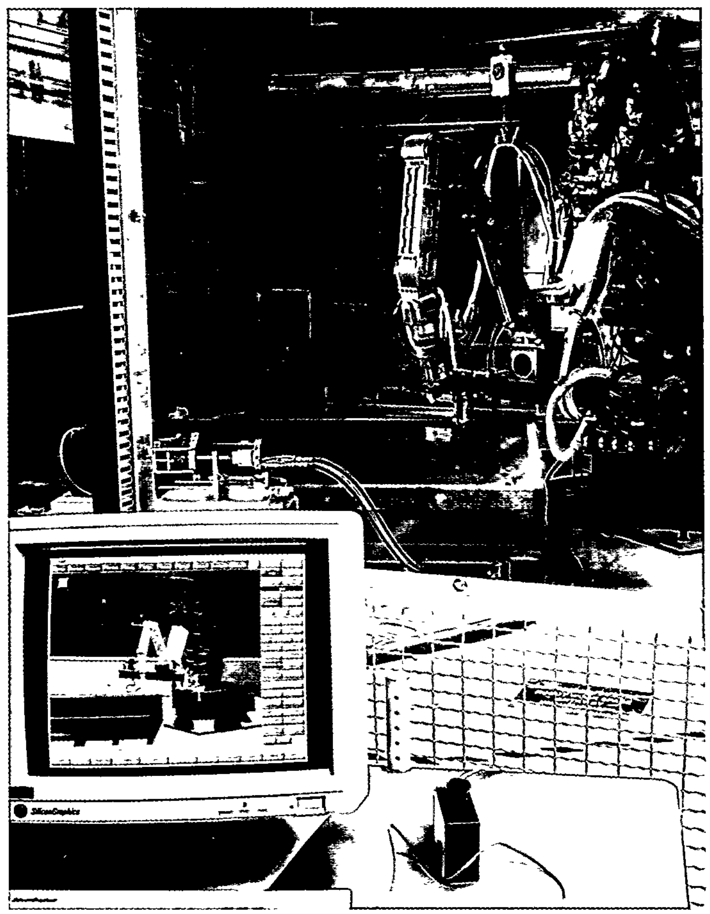
"A 30-milliwatt laser creates a plane of light," explains Sandia scientist Colin Selleck. "The laser plane follows the surface contour. A charge-coupled device camera, which can be as small as your thumb, contains a silicon chip that collects the reflected light. Triangulation techniques are used to create a three-dimensional contour map. That's the power of structured lighting—from one image, you can get three-dimensional data."

Researchers from Sandia and Oak Ridge national laboratories used structured lighting to map the surface of buried waste inside a tank at the Energy Department's Fernald facility. The task took eight

A robotic arm (left) is being tested at Sandia for gripping and removing buried pipes from underground tanks at the Hanford site.

hours and mapped features as small as 3 inches. In demonstrations conducted by Sandia at Hanford, a robot cut a pipe using only structured lighting and ultrasonic sensors.

Remote control of the robot is possible through a three-dimensional viewing technique known as virtual reality. Combined with user-friendly programming, virtual reality allows a human operator to see and manipulate the robot using a stereo viewer that gives the operator a sense of immersion in the simulated environment and simulates the motions of the robot.



A human operator can view the robot's movements remotely on a computer screen.

"What virtual reality does is allow you to interact naturally with the computer," notes computer scientist Sharon Stansfield, "without knowing all the computer languages."

To make this interaction possible, researchers construct a three-dimensional computer model of a tank interior and combine it with a stereo viewer, control stick, and software that allow a human operator to move the robot around the tank and give it verbal commands.

"As virtual reality—particularly the quick collection and presentation of three-dimensional data—becomes increasingly sophisticated, several users in different places will be able to view the same three-dimensional world," adds researcher Creve Maples.

The Hanford robot will have internal smarts and sensors to prevent collisions with objects inside the tank. Such safeguards will prevent costly or hazardous mistakes, such as a command that might cause the robot to run into a wall.

In addition, the robot will carry a pipe cutter; ultrasonic sensors; a chemical analysis lab for measuring oxygen, hydrogen, and liquid viscosity; and force sensors that will transmit resistive force to the tip of the robotic arm and ultimately to the human operator.

The robot must have a very high strength-to-weight ratio to accommodate the huge underground tanks at Hanford, which measure 75 feet wide and 40 feet tall. Each tank has a 42-inch-wide opening in the top covered by a removable lid. "We need to fit the robot arm through that hole and still reach across the radius of the tank," notes Sandia researcher Brady Davies. "We do not want to modify the tanks by adding more openings and perhaps creating more leakage problems."

Buried waste in the tanks has four main components: a salt-cakey substance, a peanut-buttery clay or sludge, liquid, and vapor that can sometimes be explosive. Sandia's responsibility is to develop robotic technologies to characterize and remediate the contents of the tanks quickly, safely, and inexpensively. Ultimately, solid wastes will likely be vitrified—hardened into a glass—and stored in barrels or moved to another site.

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RECYCLING MADE EASY

Sandia-designed system sorts plastics automatically

One of the most desirable properties of plastic—its durability—is also one of its greatest drawbacks. The stuff is so durable that kids can drop it, freezers can freeze it, dogs can scratch it, foods can stain it, and dishwashers can heat it, all without destroying it. It lasts virtually forever, even after it's thrown away.

Of course, that's just the problem. As landfill space becomes more and more limited, society can ill afford to fill garbage dumps with materials that don't easily degrade. One solution to this dilemma is recycling.

But recycling is not as simple as taking a bunch of plastics and melting them together. When one kind of plastic is mixed with another, it tends to lose its strength, or its durability, or the other properties that make it useful. Which means that soda bottles and syrup bottles and fast-food containers and grocery bags must be separated before they can be reprocessed and reused.

Sorting the items by hand is time-consuming and expensive. Recyclers would like to automate the entire process.

That is exactly what a new system developed at Sandia will do. The automated system can sort 13 items a second—fast enough to be useful to the recycling industry, says Sandia chemist Kathy Alam, who helped develop the sorter.

The Sandia system identifies plastics by the spectrum of near-infrared light they reflect and absorb. An artificial neural network that loosely mimics human learning through pattern recognition is trained to recognize each type of plastic as it moves along a conveyor belt. The neural network basically guesses what kind of polymer it encounters based on spectral readings, and then is told whether it guessed correctly. So far, several of the networks have achieved 100-percent accuracies during test runs.

In a typical recycling operation, plastics arrive from collection points crushed into bales that are then passed through a separating machine that pulls the individual items apart. The items are fed onto a conveyor belt for sorting. Finally, a blast of air is triggered that blows the item off the conveyor belt at just the right moment, causing it to land in just the right bin.

Sandia's sorting system recognizes seven kinds of plastics—the same kinds identified by a number inside a triangular recycling logo stamped on each item. Developed by the Society of Plastics Industries, the triangular logo and the

Sandia researcher Suzanne Stanton demonstrates an automatic sorting machine developed at Sandia for identifying and sorting plastics on a conveyor belt.

seven-tiered identification system are not mandatory in the U.S., but are observed by many manufacturers on a voluntary basis.

The seven categories refer to seven kinds of resins used in consumer plastics: polyethylene terephthalate (1-PETE), found in soft drink bottles; high-density polyethylene (2-HDPE), found in milk jugs; polyvinyl chloride (3-PVC), found in nonmetal pipes and sometimes shampoo bottles or other items; low-density polyethylene (4-LDPE), the primary constituent in some plastic grocery bags; polypropylene (5-PP), used in syrup bottles; and polystyrene (6-PS), found in fast-food containers, coffee cups, and some yogurt containers. The seventh category is a catchall for everything else.

Though plastics recycling is on the increase, it has not yet caught on in a big way in the U.S. However, it is already mandatory in parts of Europe, explains Alam. Germany, in particular, has passed legislation requiring manufacturers to recycle plastics.

Meanwhile, some U.S. companies are beginning to show an interest in plastics-sorting technologies. Sandia has a license with a manufacturer of recycling equipment that allows the company to use the Sandia-developed sorting technology.

Sandia researchers are also working on identifying and sorting nonconsumer plastics such as carpeting, computer casings, and electronic parts. (Carpeting is often made of nylon or polyethylene.) Ultimately, recycling companies would like to sort about 20 categories of plastic waste, says Alam, including thermoplastics in cars and computers, Plexiglas, Lexan, and nylon.

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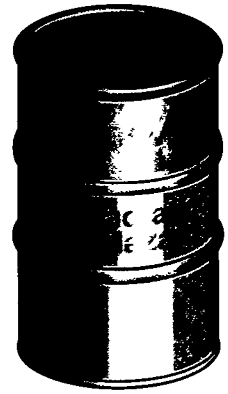
Toxic waste



Government, academia, and business become partners in landfill cleanup

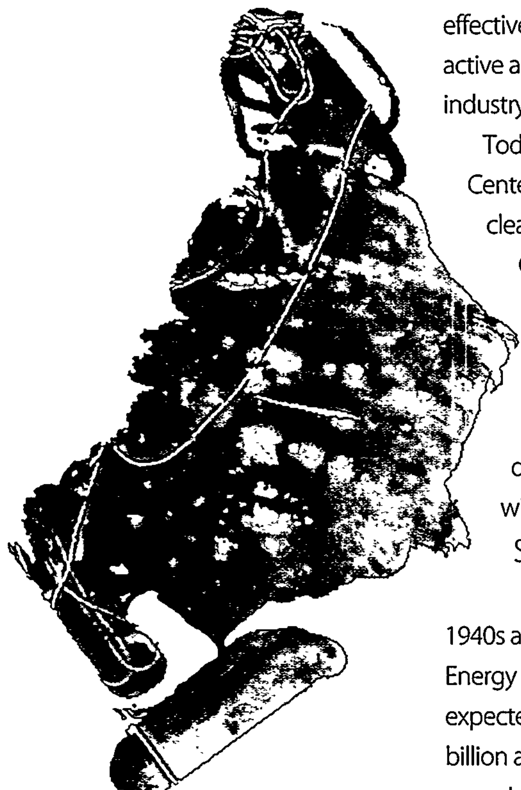
Three years ago, John Cochran, an environmental engineer at Sandia, learned of a dune buggy that could tow a trailer carrying seven magnetometers to map buried metal objects. The dune buggy was part of STOLS — the Surface Towed Ordnance Locator System — developed by the Navy to search for buried explosives.

The vehicle, which can cover more than 10 acres a day, seemed to fit the needs of the Mixed Waste Landfill Integration Demonstration at Sandia National Laboratories. This program is dedicated to demonstrating innovative and cost-effective solutions for cleaning up mixed wastes — wastes containing both radioactive and chemical constituents — while integrating the efforts of private industry, educational institutions, and government.

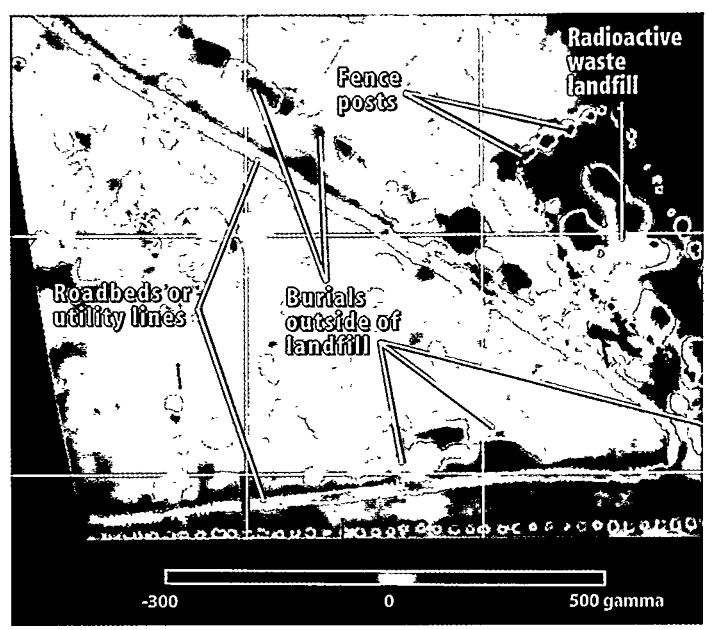
Today, Cochran, Jim McDonald of the Naval Research Laboratory, and Geo-Centers Inc. of Boston are working to adapt the system, originally developed to clean up bombing ranges, to help characterize buried hazardous waste sites. Geo-Centers Inc. has commercialized STOLS and is interested in expanding its capabilities to the waste cleanup market.

The next generation of STOLS, called the Multi-Sensored Towed Array Detection System, will use magnetometers to detect buried metals, such as underground toxic waste drums, and sensors to detect radiation and organic vapors in the air. Like the original STOLS, it will also use automated data acquisition and the Global Positioning System for navigation.

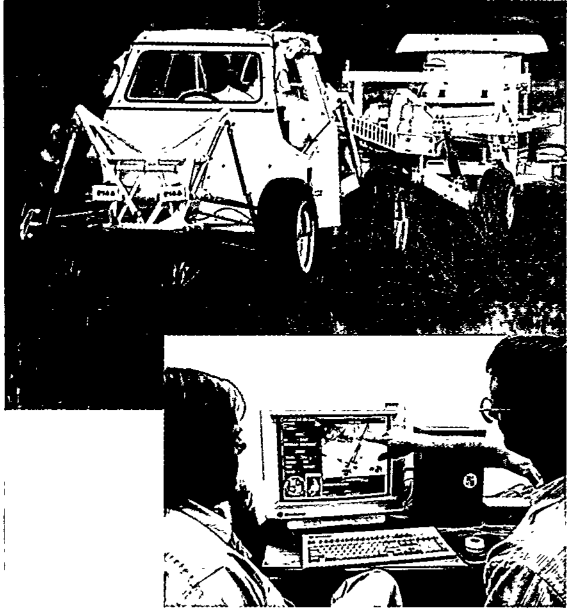
The cleanup of chemical and mixed wastes discarded since the late 1940s at Department of Energy facilities is expected to cost $150 billion and may take 30 years. In addition to STOLS, Sandia is assessing a variety of technologies to help reduce the cost of waste cleanup.



The Surface Towed Ordnance Locator System, originally developed by the Navy to search for buried explosives, can also be used to map magnetic anomalies underground, as in this image of a six-acre landfill.



Drums of radioactive waste, utility lines, fence posts, or anything else made of ferromagnetic metal can be imaged with STOLS, as demonstrated in this map of a hazardous waste landfill and the surrounding area at Sandia. To the right of the color image is a surface photograph of the same area.



Researchers Jim McDonald (left) and John Cochran study landfill images obtained with STOLS, a system that tows a trailer carrying magnetometers for mapping buried metal objects.

To characterize the waste and cut costs, MWLID researchers conduct a variety of field tests at one time to produce a complete picture of a contaminated area. New drilling techniques, sampling optimization methods, borehole location optimization, subsurface imaging, membrane liners, and analytical screening tools are some of the technologies being tested.

"The goal is to show how these individual technologies may interact," says Bob Floran, principal investigator of the Landfill Characterization and Monitoring System for MWLID.

After the characterization phase, MWLID will turn to the next phase—remediation. Of particular concern to engineers is the vadose zone—the area beneath a landfill and above groundwater. Fast-moving pollutants can easily contaminate the vadose zone and threaten underlying groundwater. Researchers are evaluating several emerging remediation technologies, such as electrokinetics to remove metal ions; extraction systems using vacuum and soil heating methods; isolation of contaminants with subsurface liners, barriers, and surface cover systems; stabilization measures to keep waste from migrating; and alteration of soil chemistry to reduce toxicity.

Successful technologies will be available for use by government and industry. "We stress the need to not only develop technologies, but also to have them used to help clean up mixed waste landfills," says Cecelia Williams, principal investigator for MWLID's technology integration and transfer system. Sandia is developing partnerships with state, local, and tribal governments, universities, public organizations, and private industry to broaden knowledge and use of emerging technologies.

In addition to the further development of STOLS, other MWLID technologies that have been commercialized by private industry are the SEAMIST membrane liner that was purchased by Eastman Cherrington Environmental Co. of Houston, and SitePlanner, a sampling methodology available from ConSolve Inc. in Massachusetts.

Other MWLID technologies are nearly market ready. They include PLUME, a system that provides geostatistical routines to optimize the number and location of boreholes and samples for site characterization, and a field analytical screening method known as adsorptive stripping voltammetry, which measures heavy metal concentrations in soils.

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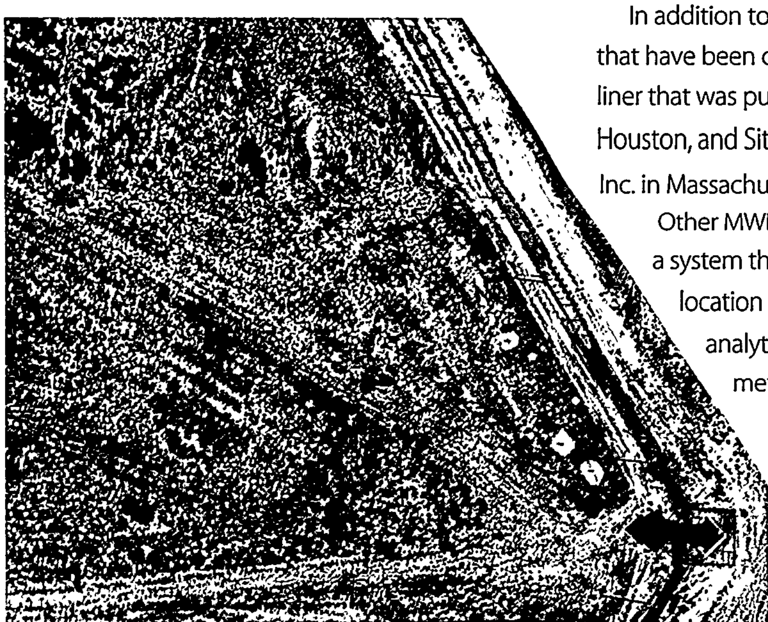
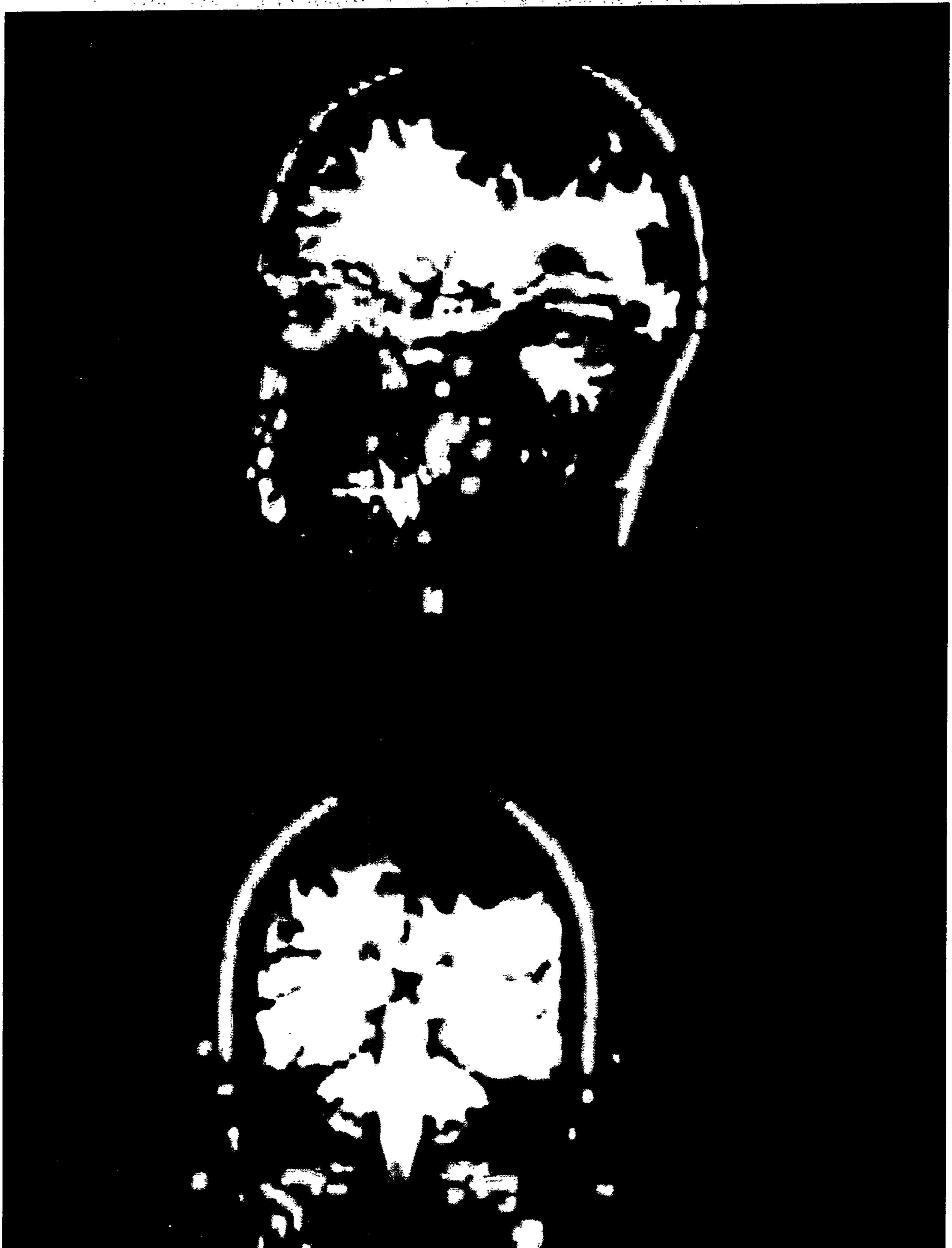
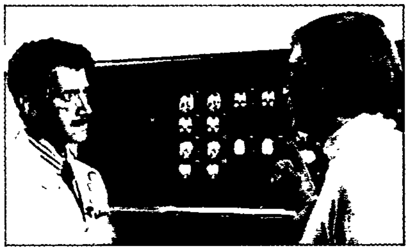
Safety & Risk Assessment
(505) 848-0415





HEALTH CARE



Dr. William Orrison (left) and Carl Diegert view a conventional X-ray presentation of brain anatomy and function.

a delicate operation

Massively parallel computing could help guide brain surgery

With every passing year, medical researchers come a little bit closer to unraveling the mysteries of the human brain. Today, Sandia scientists are working with doctors to develop three-dimensional computer imaging techniques that may one day make it easier to successfully complete that most delicate of operations — brain surgery.

"Often in surgery or medical exams, you want to see the data immediately," says Sandia scientist Carl Diegert. "But the medical data set is huge; you have to decide what's important. One of our innovations is that we've extracted and distilled the data from magnetic resonance images so that it can be viewed and used on a conventional computer workstation."

Another innovation is the superimposition of three-dimensional computer models with actual video footage of surgery taking place. This fusion of the two media will eventually help guide doctors through the surgery process, notes Diegert.

To make the vast amount of data from MRI scans more manageable, Sandia computer scientists are developing algorithms that analyze the data and display only what is critical in a three-dimensional image. The algorithms sort through the scans and identify necessary features, such as lighter-colored surfaces that might represent blood vessels or a lesion in the brain. Ultimately, scientists hope to use this process to assist in real-life surgeries.

Diegert and a Sandia videographer recently witnessed and videotaped a brain operation conducted by Dr. Nevin Baldwin, a neurosurgeon at the Veteran's Affairs Hospital in Albuquerque, New Mexico. Doctors were worried the patient might have a recurring brain tumor, but it turned out to be infected tissue, which Dr. Baldwin removed during the surgery.

Diegert is now working with Drs. John Sanders and William Orrison of the UNM School of Medicine and the VA Medical Center Department of Radiology to use magnetic resonance images from the same patient to build a three-dimensional computer model of the patient's brain. The MRI scans were sent to Diegert over a computer network — a quick and effective way to share critical information. Diegert will review the three-dimensional computer model with the surgeon to see if it would have been helpful during surgery.

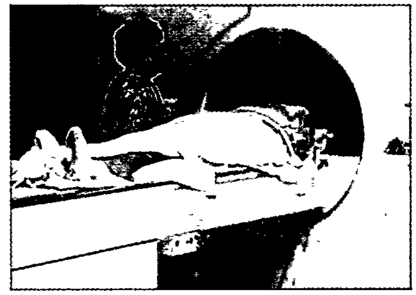
"Radiologists typically take half an hour to compute a single three-dimensional MRI view of the brain," notes Diegert. "At that rate, it would take a couple of days to prepare complete three-dimensional images of a whole brain. But we can do it much more quickly with massively parallel computing. Our process is 100 to 1,000 times faster."

Or, as Baldwin says, "When it's the brain, time is of the essence."

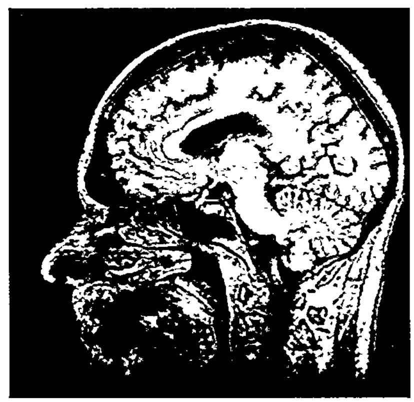
Although supercomputers, such as the Intel Paragon model recently installed at Sandia, are quite expensive, in two years they are expected to be more economical for hospitals, leading to a transition to parallel computing.

One of the advantages of MRI scans is that they are relatively easy to adjust to show whatever features or specific surfaces the doctor is interested in viewing, such as arteries or lesions. This is because the very high magnetic field in an MRI machine causes water molecules inside the body to align. When the machine emits a radio signal, the aligned water molecules absorb the signal, tip slightly, and send the signal back. When this signal is returned, it is used to produce an image of the aligned molecules. By changing the parameters slightly, the radiologist can view different images of body tissue. Improvements in automatic data reduction make such large-scale observations clinically useful.

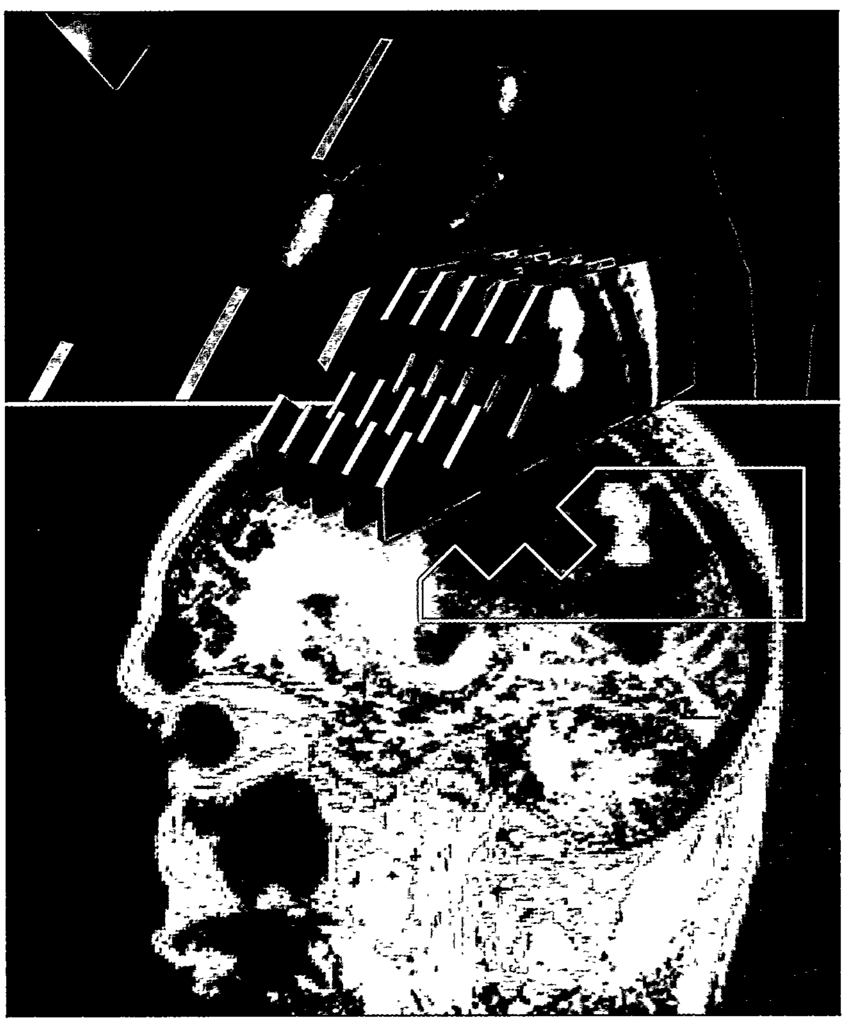
A magnetic source machine that senses the magnetic field generated by neurons in the brain observes brain function.



A magnetic resonance machine observes brain anatomy.



A black-and-white magnetic resonance image shows the brain's anatomy.



Top left:
In this enlargement, the lesion is shown in green; the surgeon must avoid the area shown in red to prevent motor damage during surgery.

Middle left:
The extent of the lesion is clearly displayed in a three-dimensional "bread loaf" of slices of the data.

Bottom left:
A color-enhanced magnetic source image shows the lesion in the upper portion of the brain.

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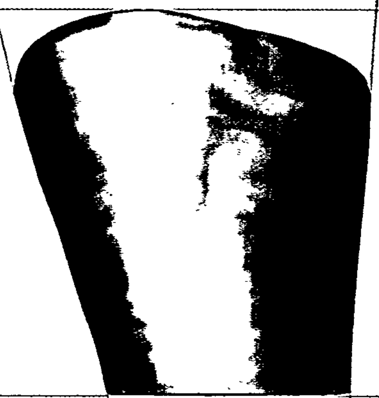
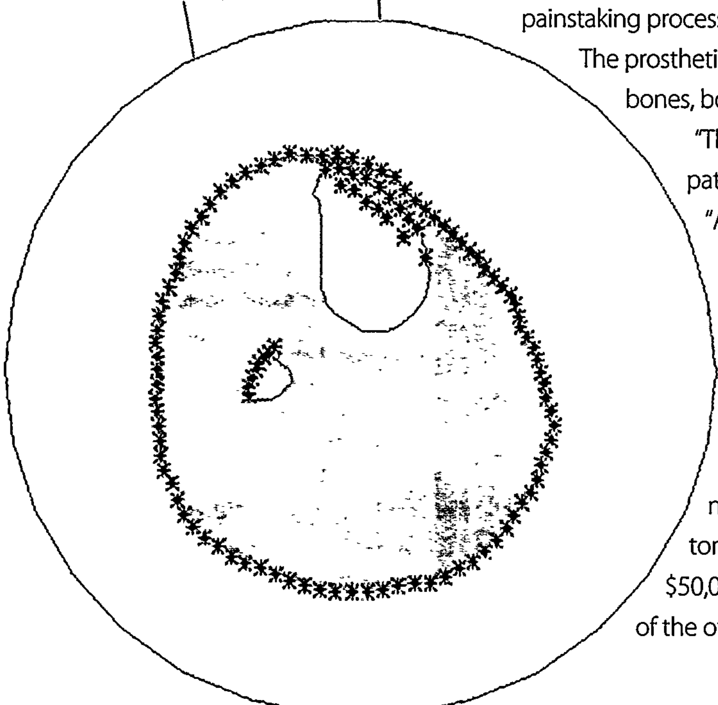


a better fit

Joint project with the University of Texas focuses on design of prosthetic devices

In the above diagram, a computer model predicts the scope of the three-dimensional data that can be collected from images of the human leg obtained with ultrasound.

Below, a computer model predicts the completeness of cross-sectional images of skin and bone surfaces. The white areas are bone.



Each year, some 60,000 people in the U.S. lose a leg to amputation. The cause may be diabetes, peripheral vascular disease, gangrene, bone cancer, other diseases, or accidents.

Often, prosthetic devices enable a patient to continue to participate in physical activities such as walking or running. But prosthetic devices are expensive, ranging from $3,000 to $15,000 each, and they must be replaced when they no longer fit due to muscle atrophy or bone growth. Patients need three to five prosthetic devices in the first year and a new one every four years after that. The estimated cost to patients of all these devices is about $1 billion a year.

Sandia researchers are helping improve the fit and fabrication of new prosthetics. Together with researchers at the University of Texas Health Science Center at San Antonio, they are applying ultrasound techniques and computer-aided design to make a device that fits the patient's remaining bone and muscle tissue comfortably.

Currently, prosthetists make artificial limbs by hand, a time-consuming and painstaking process that often requires several fittings and adjustments. The prosthetic device must not apply pressure to the patient's bones, both to avoid pain and to prevent pressure sores.

"The prosthetist makes a plaster impression of the patient's leg," says Sandia project leader Alan Morimoto. "A lot of time goes into manually getting an impression and making biomechanical adjustments."

Just as ultrasound can be used to produce images of arteries or fetuses in a doctor's office, it can also be used to make images of the limb that remains after amputation. Ultrasound is less expensive than other imaging techniques such as magnetic resonance imaging or computer-aided tomography; an ultrasound machine costs $40,000 to $50,000, compared with several million dollars for either of the other machines.

The Sandia-University of Texas project is focused on below-the-knee amputations. To improve the fit of prosthetics, researchers scan the remaining healthy portion of the leg ultrasonically to produce a three-dimensional model of the skin surface and underlying bone surfaces. "Images generated so far show great potential for using this technique to design better prosthetics," says researcher Scott Strong, whose specialty is image and signal processing.

A circular tub filled with water rotates around the leg while a transducer behind a window in the wall of the tub transmits and receives ultrasonic energy to produce a planar image or cross section of the leg. A scan takes about 20 seconds.

"By keeping the transducer out of the tub, we reduce turbulence in the water that would move the patient's leg and distort the data," notes Morimoto.

Sandia scientists have also developed computer models that predict the surfaces of skin and bone — in other words, the completeness of the data — that the ultrasonic imaging will provide. These models have been extremely accurate in visualizing the data, and have allowed researchers to determine in advance how much data to collect.

Researchers at the University of Texas perform biomechanical adjustments to the ultrasound scan data in a computer-aided design system. This system develops fabrication specifications based on the data and sends them to a computer-controlled machine that fabricates the prosthesis. In time, this technique may become part of an advanced manufacturing process and eliminate the need for hand-crafted prosthetic devices.

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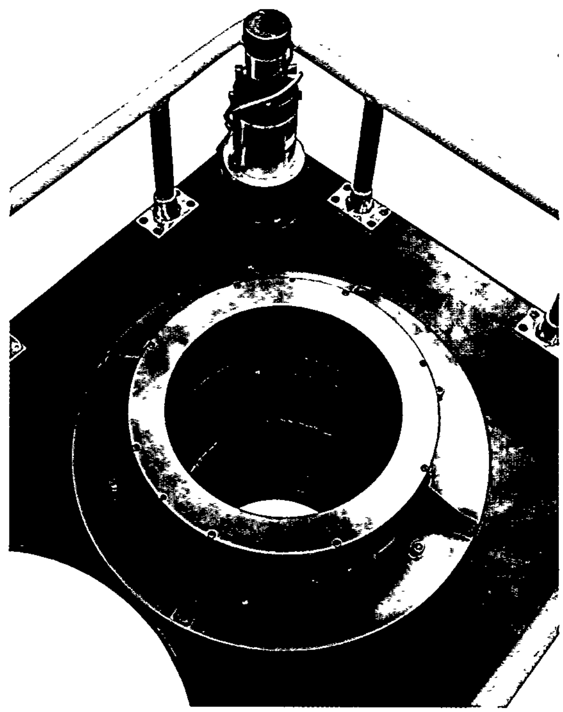
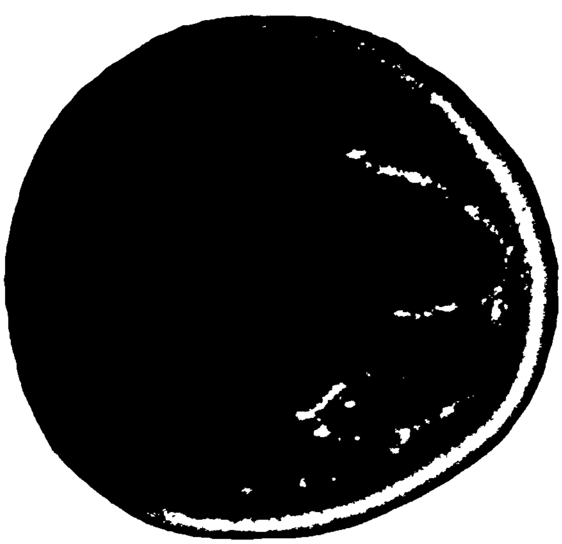
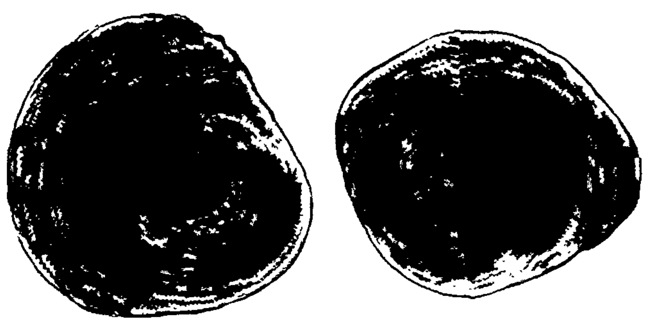


To obtain ultrasound images, a patient inserts the healthy portion of the leg into a circular tub (above) filled with water.





Actual ultrasound images show skin and bone surfaces inside the human leg. Computer simulations at Sandia have closely approximated the completeness and usefulness of such ultrasound data for improving the fit and fabrication of prosthetics.

shining a laser for burn surgery

Biomedical technology transfer agreement will help reduce trauma of treatment for severe burn victims

For all its wonders, modern medicine is far from gentle with severe burn patients. Every year, more than 100,000 people in the U.S. suffer severe burns. In some ways, treatment of these burns hasn't progressed much since the days of the Civil War: a surgeon, using a scalpel, "fillets" the patient's skin, removing dead skin until blood—a sign of live skin—is visible.

This procedure requires massive transfusions to replace lost blood, adds to the disfigurement already caused by the burn, and involves slow and extremely painful recovery. Furthermore, the patient's chances of dying are proportional to the area of skin that is severely burned—the larger the burn, the less likely a recovery. Annually, the total cost of treatment of severe burns is estimated to exceed $2 billion.

But help may soon be on the way. Medical researchers at Massachusetts General Hospital and scientists at Sandia National Laboratories are designing a better way to treat severe burns. The goal of their $13.4-million cooperative project is to reduce patient trauma by using a laser beam to remove burned skin and automated diagnostics to minimize loss of live skin and minimize blood loss, the main cause of death in burn patients. Heavy bleeding often prevents a successful skin graft after the burned skin is removed.

Their joint effort is the first biomedical Cooperative Research and Development Agreement at Sandia. The program is funded by the Department of Energy.

In the new burn treatment procedure, the laser will replace the scalpel.

"Doctors at Massachusetts General Hospital, a national leader in burn treatment, figured out somewhat fortuitously that laser ablation, if done correctly, kills only a very thin layer of healthy skin beneath the dead skin," explains materials scientist Ned Godshall, of Sandia's Instrumentation Engineering and Technology Department. This 100-micrometer-thin layer of skin is so thin that nutrients from below can still get through it and keep the skin alive. Yet this layer seals the blood and stops the profuse bleeding from preventing a good graft.

"The irony is that you treat a burn victim by burning the victim slightly," he adds.

A new diagnostic system will direct the surgeon-controlled laser to remove as little live skin as possible. In conventional treatment, a surgeon removes layers of skin until blood is visible, because blood only flows through live, healthy skin. Sandia scientists are investigating a variety of ways to distinguish the demarcation line between healthy and dead skin, which often look the same to the naked eye. Researchers will begin by studying the method currently in use at MGH's Wellman Laboratories of Photomedicine, in which doctors inject indocyanine, a green dye that fluoresces when it comes into contact with laser light, into a patient's blood.

Scientists will also experiment with other sensors, computer modeling, robotic manipulators that can move the laser beam around and turn it on or off as needed, and different wavelengths of light to see how they are reflected or absorbed by dead vs. live tissue. Sandia also brings its expertise in ensuring system safety and reliability to the high-power laser burn debridement project.

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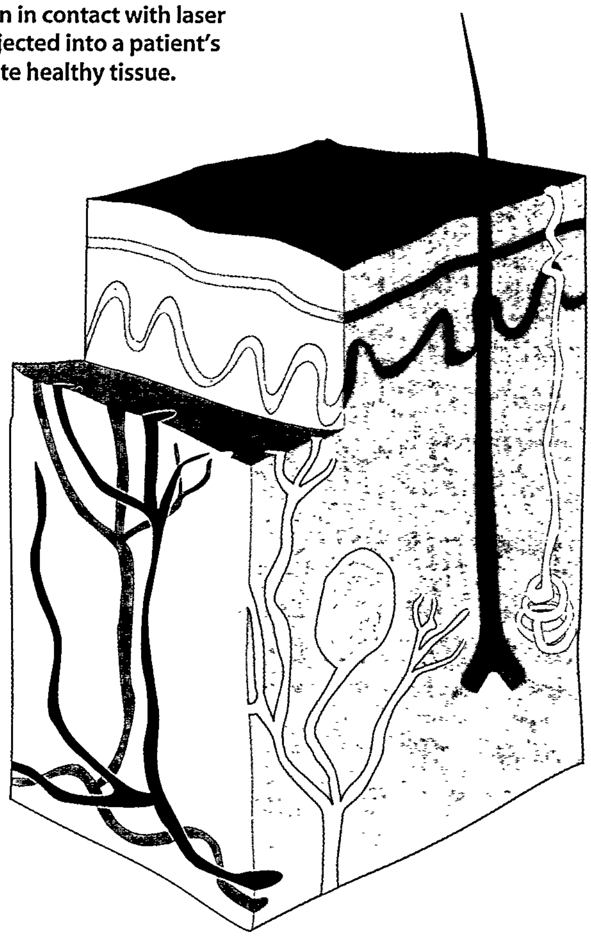
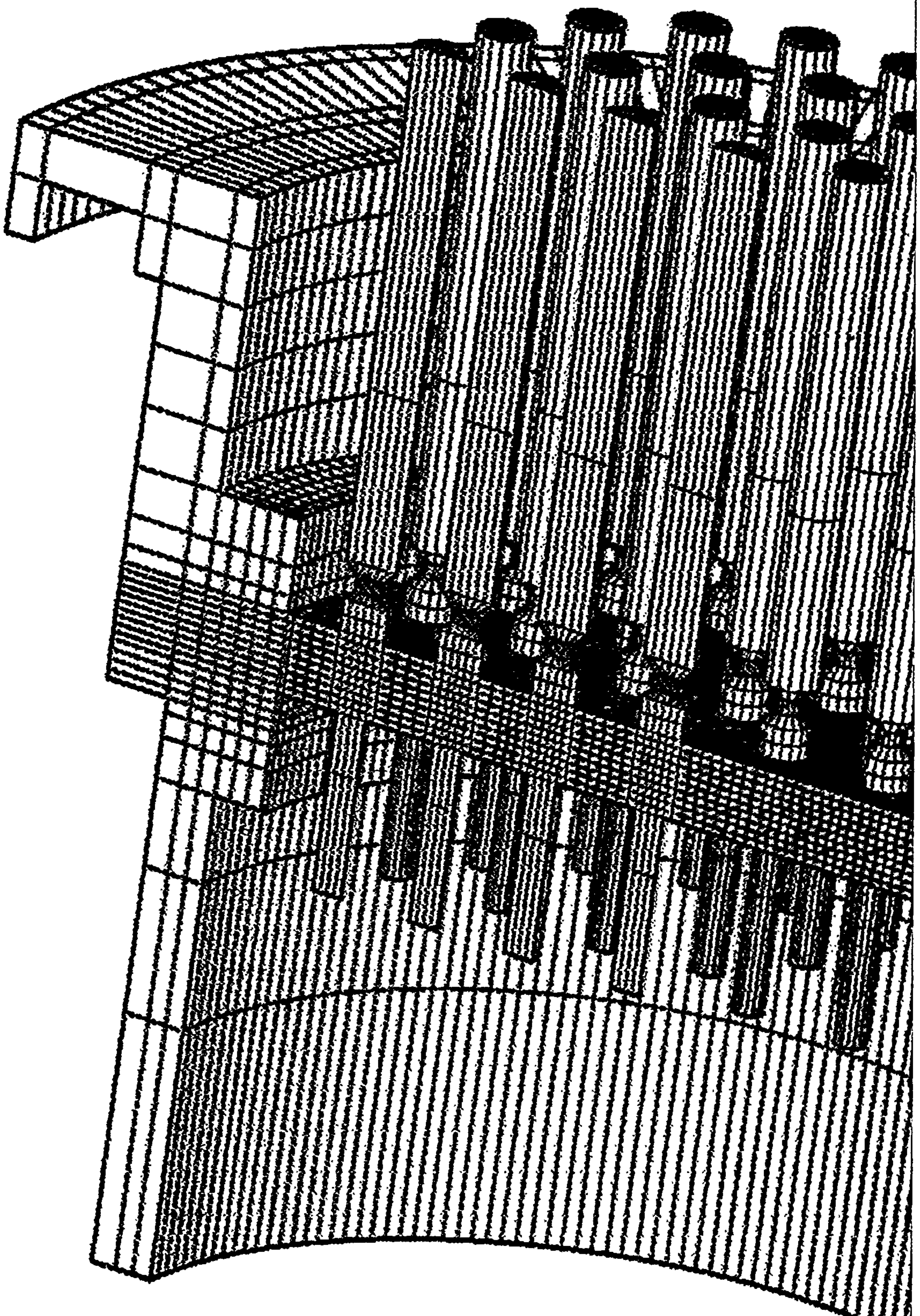
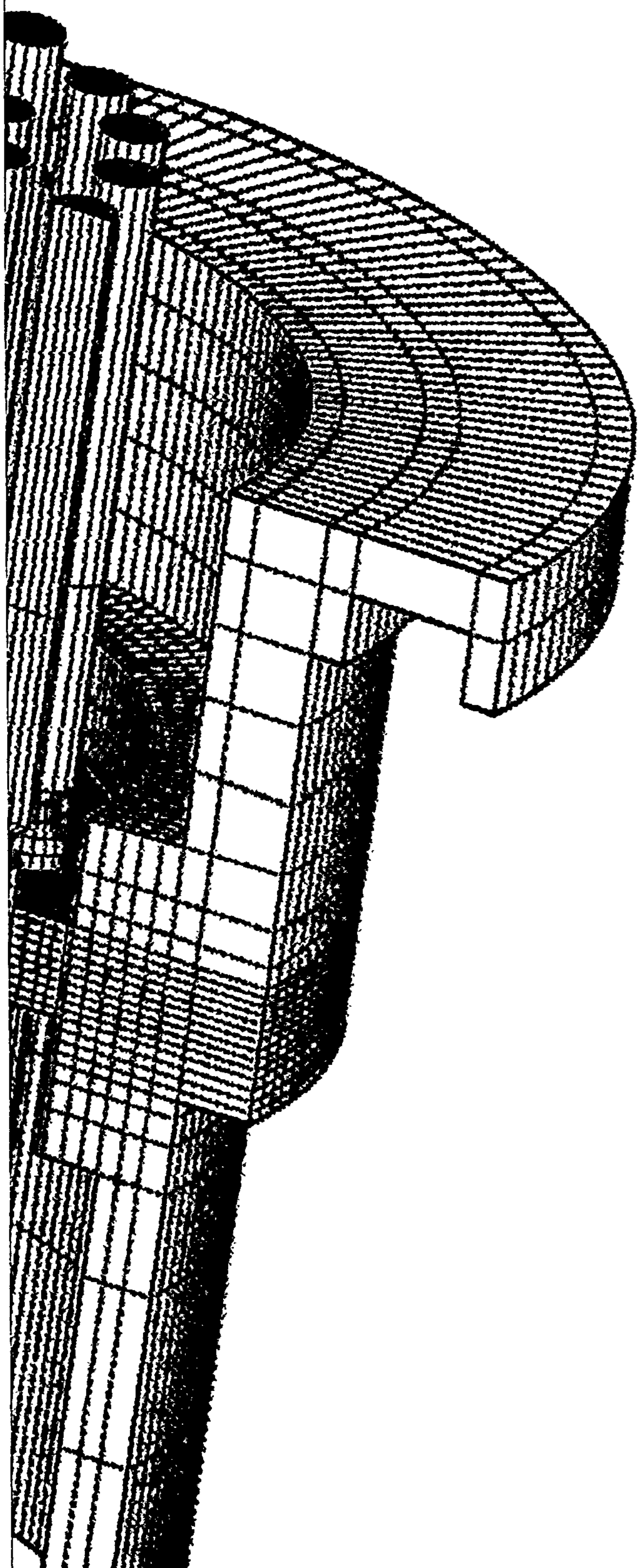
Blood vessels that carry nutrients to skin are destroyed when tissue is burned. However, Massachusetts General Hospital and Sandia are working on a new treatment method that uses a high-power laser guided by a sensor instead of a scalpel to remove only burned skin and leave healthy skin intact.



Indocyanine, a green dye that fluoresces when in contact with laser light, can be injected into a patient's blood to indicate healthy tissue.





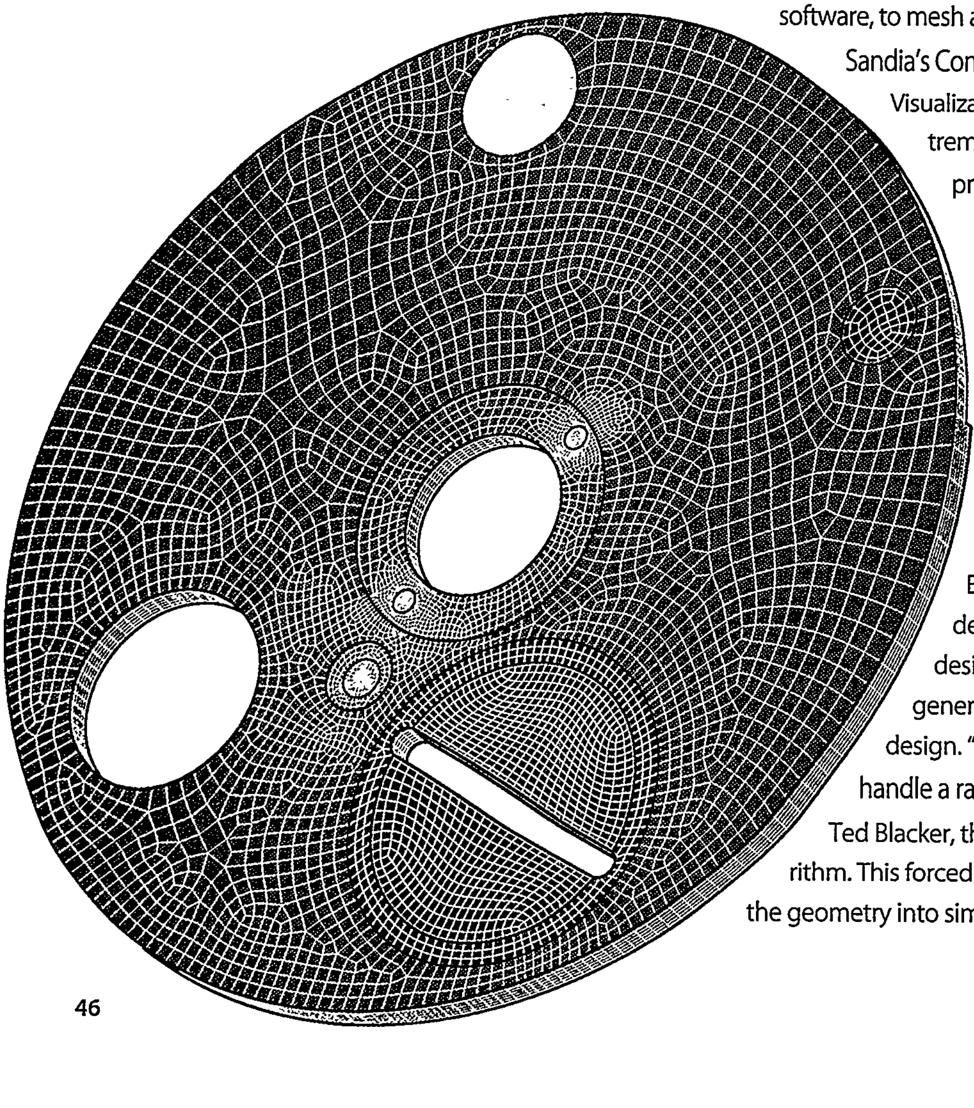
INFORMATION/COMPUTATION

Meshing 3-D surfaces for quicker design

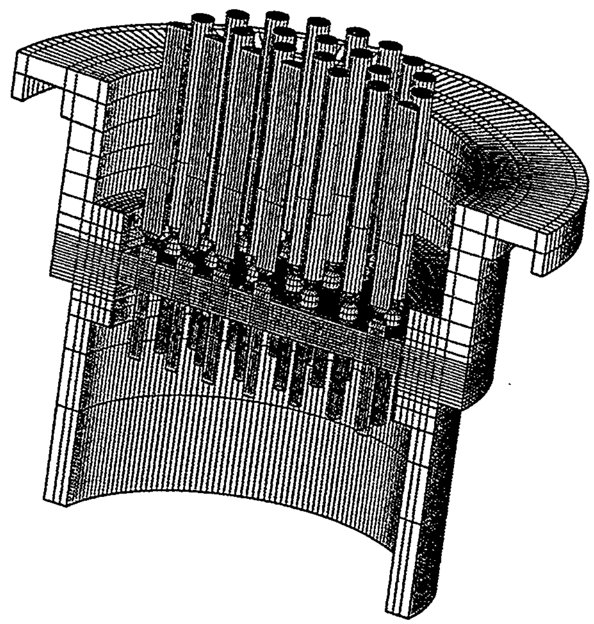
New "paving" algorithm speeds product analysis

Sandia simulation experts have developed new algorithms that dramatically shorten the time required to mesh models of complex geometries and make it much easier to model three-dimensional surfaces. These advances have attracted the attention of U.S. industry and have led to the development of a consortium to commercialize this technology. Ford Motor Company is one member of the group, as are several software and engineering companies.

Mesh generation is the creation of a computer model of a tangible object; the model uses meshes (looking like grids on the computer screen) to represent the surfaces of the object. The intersections of the meshes define points where displacement and stress, for example, may be calculated. "It can take four to six weeks, using typical software, to mesh a car design," says Johnny Biffle, of Sandia's Computational Mechanics and Visualization Department. "This has a tremendous impact on the design process and on design analysis."



The main point of Sandia's software is to relieve engineers and systems analysts of the job of directly generating the meshes in a computer program; instead, the new algorithm, called paving, gives each user tools for describing geometries and for automating the meshing process. Essentially, the goal is to free design engineers so that they can design, while the computer program generates the representation of the design. "The old algorithms could only handle a rather limited surface shape," says Ted Blacker, the inventor of the paving algorithm. This forced the designer to manually break the geometry into simple pieces that the old algorithms could handle. The new paving algorithm is far more general. "We can now generate mesh on a complex section of an object, such as the entire fender area of an automobile, or even the entire object, thus providing a three-dimensional surface representation automatically," says Blacker. One of the main uses of the mesh representations is in impact analysis, showing changes in shape as external forces crunch objects modeled by meshes on the computer screen.



The new paving algorithm has won a 1993 R&D 100 award, presented by *R&D Magazine* to the most significant technical products of the year. The mesh-generation algorithm originated in Sandia's defense work on safety systems for nuclear weapons. These new applications show how defense expertise, developed under DOE Defense Programs funding, can be applied to industrial needs. "This new software technology can reduce design time, and therefore reduce the time to market of products," notes Biffle. The next step for the Sandia meshing experts is to develop automated meshing for three-dimensional solids, showing how external forces can deform or change materials in a volumetric representation. "Every advance in modeling and simulation technology can help U.S. companies become more competitive," Biffle says. "This work is applicable to any company that uses analysis to improve the design of its products."

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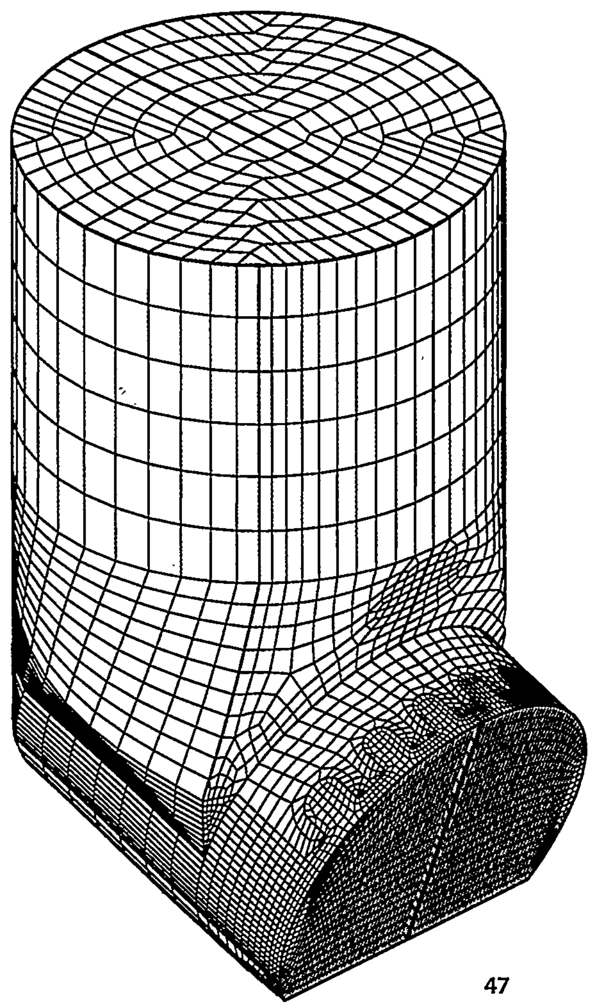
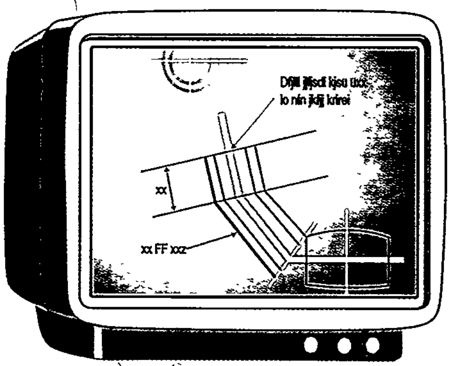
Computational Mechanics and Visualization



Left, the safing wheel of the stronglink system for a nuclear warhead. Above right, a lightning arrester connector showing the hermetic glass seal in the center of the device. Right, a computer meshing of a wellbore bit in a design project to improve longevity of the bit. In all these projects, the new meshing algorithm provided more rapid design and more accurate simulation than previous methods.



Industry ties

From high-speed computing to business networking, Sandia improves electronic communications

Whether establishing business contacts or solving engineering problems, workers of the future will rely upon knowledge as close as the nearest desktop. By punching the right keys on a computer, scientists and businesspeople will be able to design products in three dimensions, simulate manufacturing processes, or consult data bases of environmental technologies in use around the world.

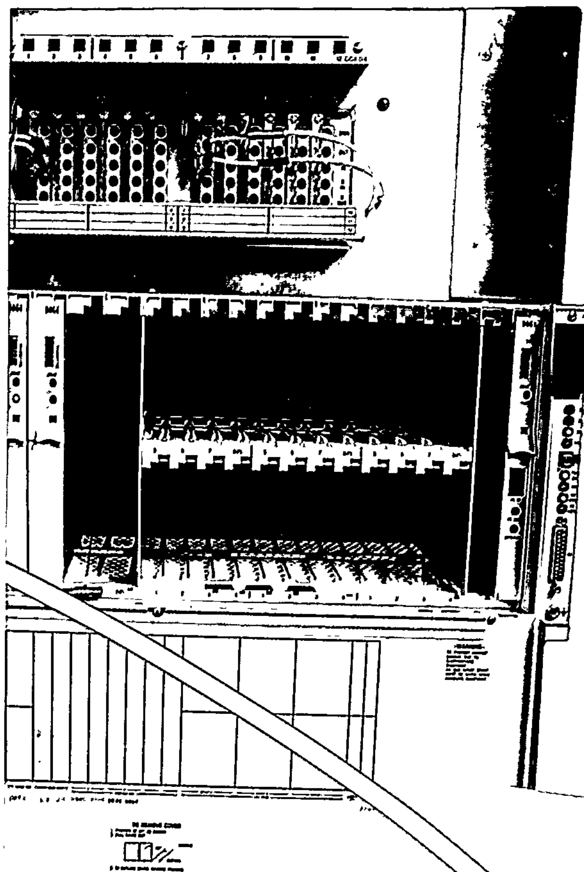
America's investment in nuclear weapon research at the Energy Department's national laboratories such as Sandia has spawned development of some of the most advanced computing and communications expertise in the world—expertise that is now being shared with the private sector.

One means of sharing such information is TIE-In, Technology Information Environment for Industry, a technology retrieval system at Sandia designed to give industries remote access to the Labs' capabilities and solutions at minimal cost.

"This is a pilot project to use computer and communications technologies to develop a mechanism for providing companies of any size with the ability to use solutions at the Labs," says project leader Jim Ang.

For example, an engineer seeking to improve welding processes for building a machine part can use welding process simulation and design programs. A banker seeking information about security systems can access computer tools for physical security design—without having to be a computer expert or structural engineer.

This is because one of the unique features of the TIE-In system is user-friendly software that guides users through the process of finding intelligent solutions to their particular problems. The system incorporates on-line training and education materials as well as graphical interfaces that show the user in pictures what is described in technical language. Remote access is possible via telephone or Internet connections.



In time, this project may serve as a prototype for a broader system providing use of technologies at all the national laboratories as well as industry and other sources.

Sandia is also leading the way in establishing high-speed, long-distance computer data networks. Recently, Sandia consolidated its supercomputers at its New Mexico site and built two high-capacity, private, encrypted networks linking users at its New Mexico and California sites. This network is a forerunner of the "information highways" expected to serve future needs for high-capacity transmission of computer data.

"Sandia's mission is changing," notes project manager Peter Dean, "to focus more on collaborating with industrial partners. The computer consolidation supports this change by freeing up the Labs' largest Cray supercomputer to handle unclassified work."

The system processes multiple high-speed data paths over a 1,100-mile line. It uses the Digital Signal 3 transmission standard and Asynchronous Transfer Mode technology to transmit data over existing fiber-optic land lines at 44.736 megabits (one megabit equals 1 million bits of information) per second.

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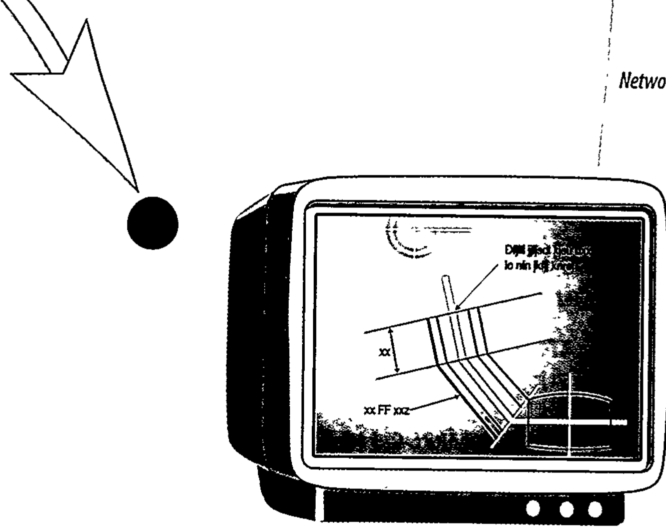
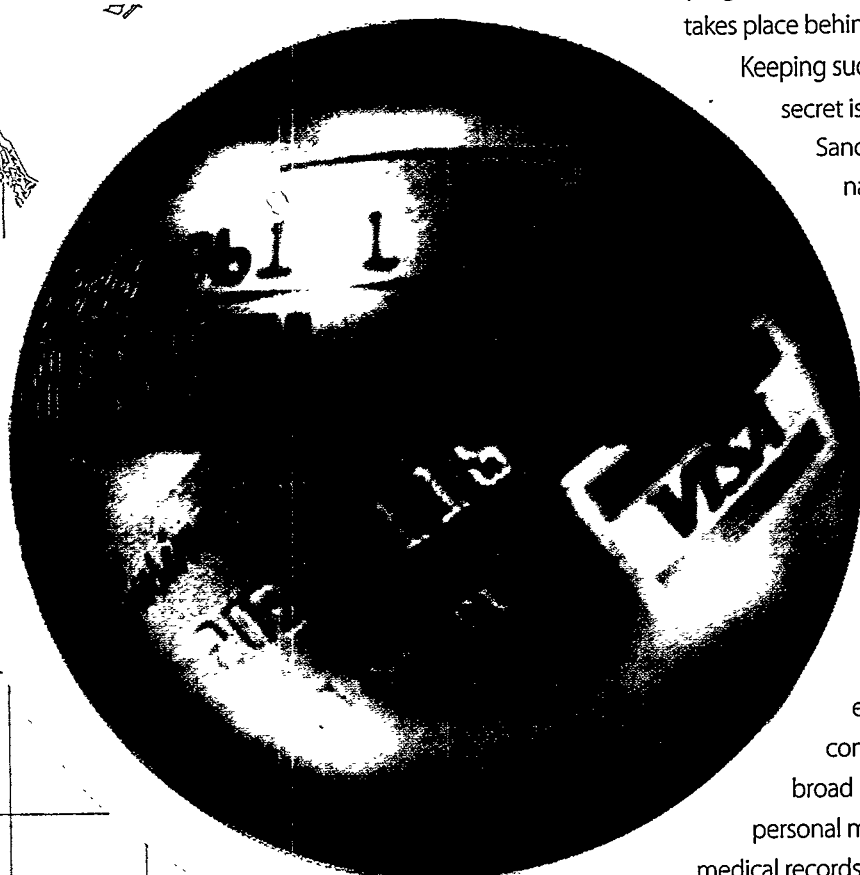


A special high-speed, long-distance computer network connects supercomputers at Sandia's New Mexico site with users at Sandia's California site. A new technical solution resource developed at Sandia, known as TIE-In, is giving industry users remote, electronic access to capabilities and expertise at the Labs.

Protecting information

In the world of nuclear weapon development, or any other military program, much of what transpires takes place behind closed doors.



Keeping such information top secret is a responsibility that Sandia—like all the national laboratories—has taken very seriously during decades of weapon design. Now, with funding from the Department of Energy, Sandia scientists are refining and applying this expertise to help ensure the confidentiality of a broad range of sensitive personal matters, including medical records and bank accounts. They are also working to improve the reliability of computerized communications lifelines, such as telephone networks.

From medical histories to credit card accounts to telephone voting, Sandia is helping design ways to safeguard confidential data

"Consider, for example, a medical records data base," says Sandia computer scientist Sharon Fletcher, of Sandia's Information Surety Department. "It must give a user access to only those levels of information the user is authorized to see—be that person a doctor, an insurance provider, a lab technician, or a patient."

To accomplish this, the network's designers must first understand exactly what information needs to be protected, from what or whom, under what conditions, and to what degree. They must assess all the risks involved. And they must design security into the system right from the start, not tack it on later in the form of an antivirus program or mechanical lock.

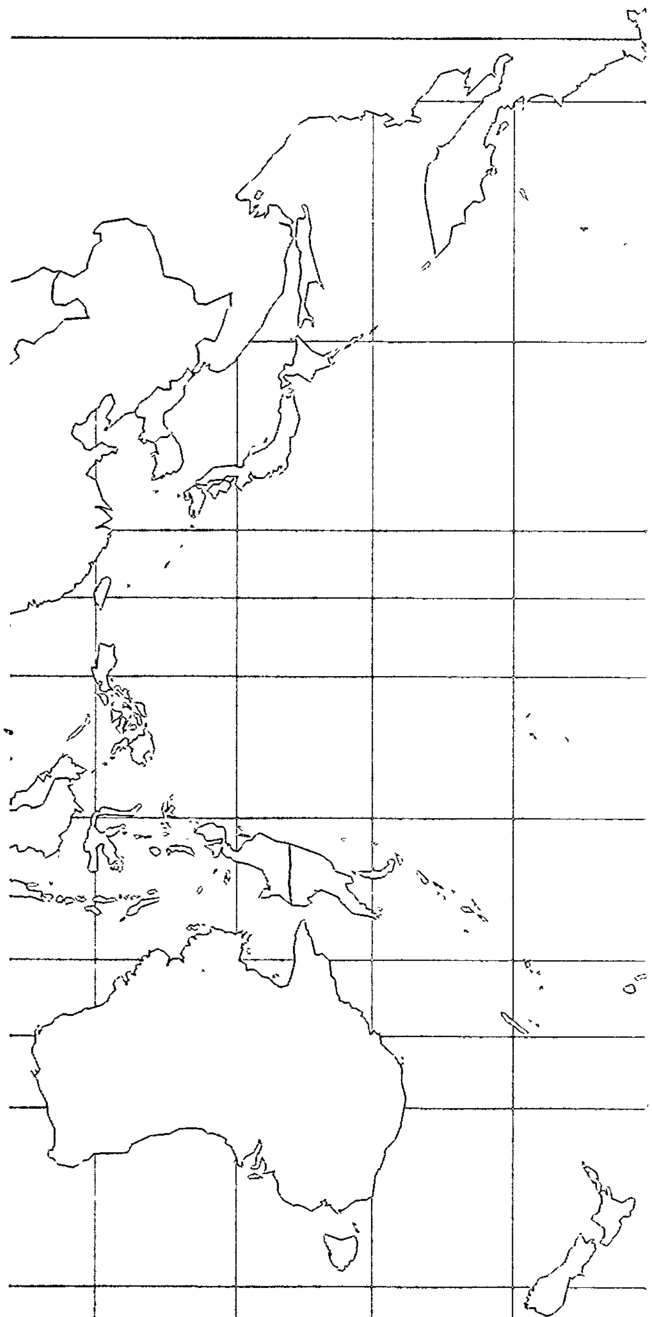
"There are all sorts of advantages to having a standardized approach to medical record-keeping," notes Fletcher. "It saves money, eliminates extra medical tests or exams that have already been done, provides quick access to critical patient records, and makes better research possible. Eventually, the national goal will be a standardized system accessible to all. But before any large-scale system can become a reality, patients and health care employees need to be assured that the system will be protected against unauthorized use.

"You have to be sure the whole system assures people of anonymity," adds Fletcher, "and at the same allows research statistics to be gathered. You also have to ensure that the information is accurate."

To address these problems, which in the past have often been tackled piecemeal by people with particular specialties, Sandia has developed an interdisciplinary approach that teams the talents of many kinds of computer experts to solve security problems. An internal group, called the Information Surety Affinity Group, has published a directory that will make it easy to refer anyone from industry to the appropriate person for assistance and expertise. The group comprises experts in software surety, cryptology, scientific computing and computer security, information architecture, human factors, software development, and risk assessment.

Some hands-on projects are already under way. Sandia is currently working with a California company to incorporate security into a doctor-oriented medical system that keeps patient records and assists with diagnosis. A prototype system being field-tested at the Stanford University Medical Center places multimedia files at the doctor's fingertips—not only written text, but X-rays as well.

Sandia also successfully.demonstrated a vote-by-phone election at the lab and a local high school. The next step is a thorough evaluation of the security risks in such a system. Sandia is helping the state of New Mexico explore information systems that will support the state's health care policies and reduce health care costs. One goal is to build a regional health care alliance that will include Sandia and Los Alamos national labs, health care providers, and government. In addition, Sandia is working with banks to curtail credit card fraud, with AT&T to eliminate phone outages, and has discussed its technology with the IRS and the FBI, two agencies in the process of building new information systems.



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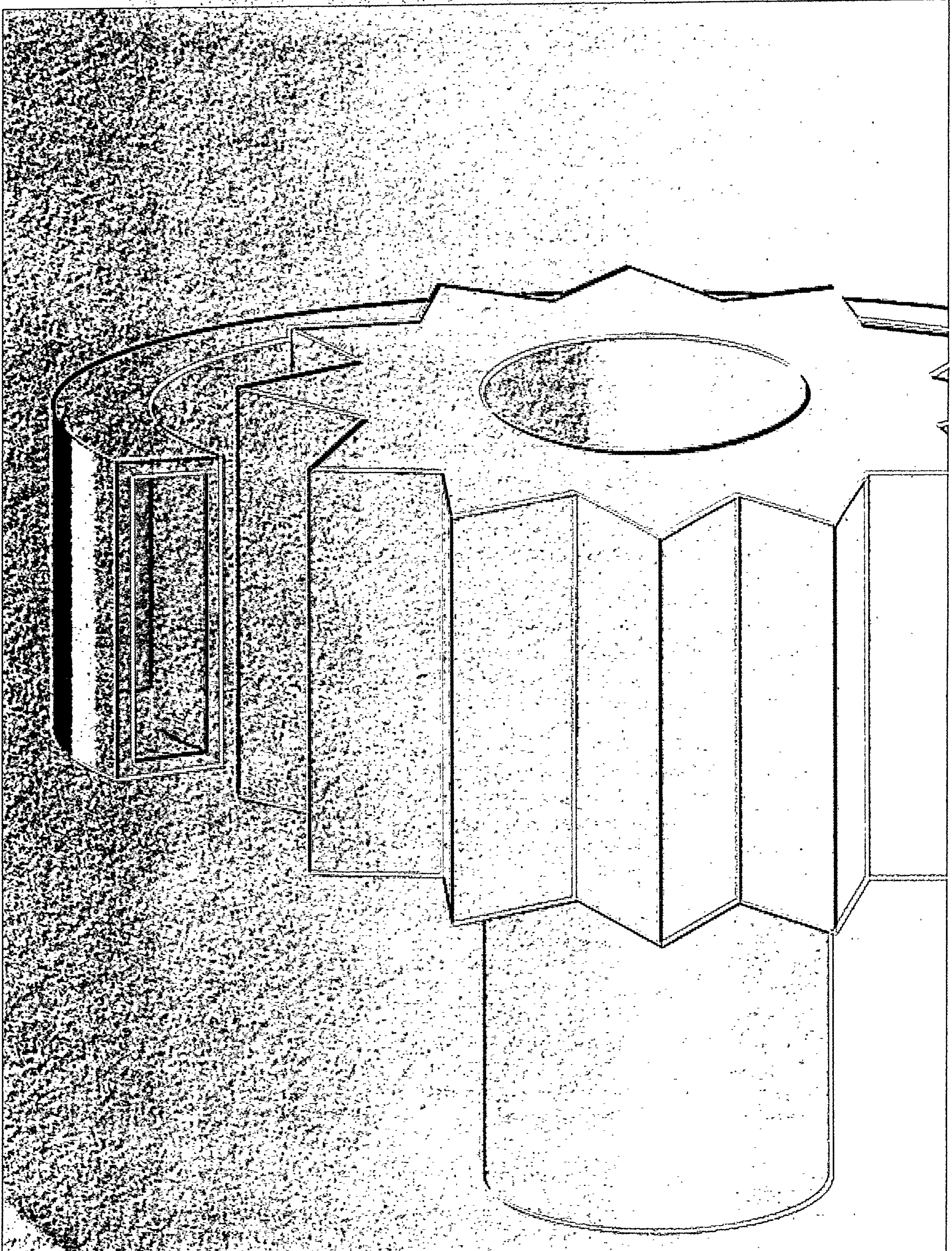
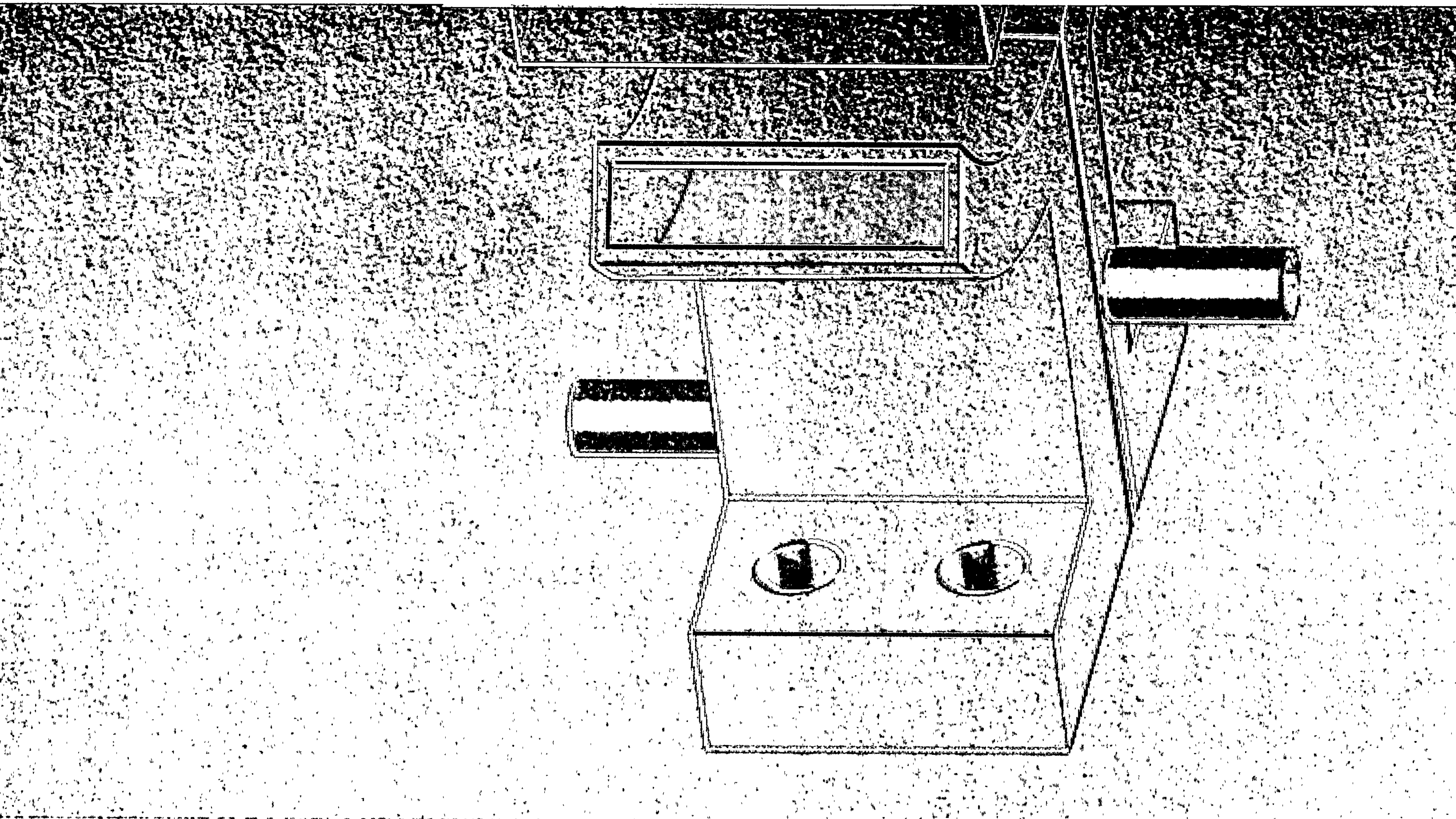
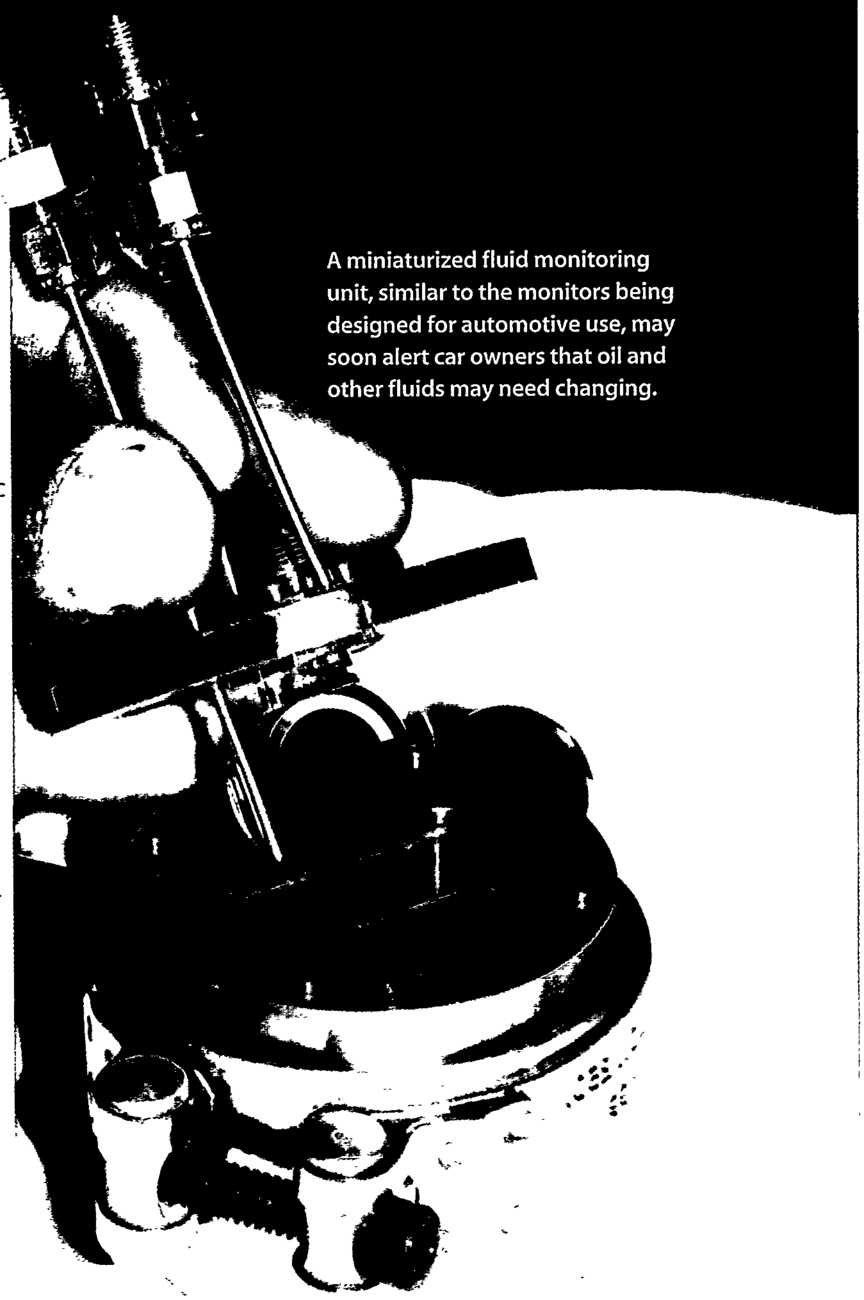




TRANSPORTATION

GM CRADAs open avenue for Sandia's technology

Sandia and GM look at several technologies to lessen environmental impact and improve manufacturing processes

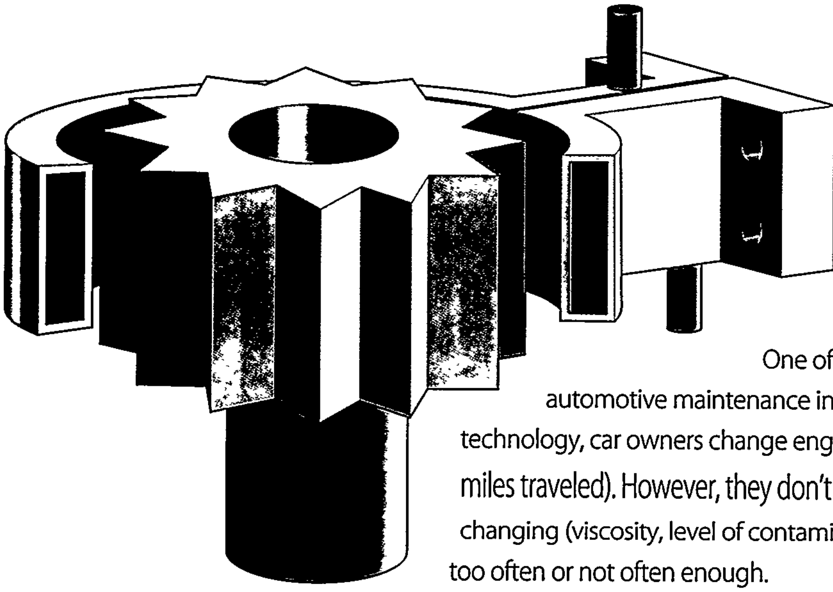


A miniaturized fluid monitoring unit, similar to the monitors being designed for automotive use, may soon alert car owners that oil and other fluids may need changing.

General Motors Corporation is working with Sandia scientists and engineers to move technology from the labs into the cars of the future. Several cooperative research and development agreements between GM and Sandia are the vehicles for this technology transfer effort. These CRADAs cover a wide range of technologies, including metallurgy, software development, and microsensor applications.

The GM Saginaw Division and Sandia's Engineering Sciences, Materials and Process Sciences, and Electronic Subsystems centers are cooperating on research into the induction hardening process for car parts. Induction hardening uses a powerful magnetic coil to induce current in a steel (ferrous) part placed inside the coil; the induced current heats the exterior and near-exterior areas of the part, which is then quenched. This process hardens the heated areas but leaves the interior in a more ductile state, yielding parts that wear well on the surface and resist fatigue in the interior.

Unfortunately, the parameters of the induction heating process are not clearly understood, and waste and scrap cost automakers millions of dollars each year. Sandia's researchers have begun four tasks to help improve the induction hardening process: process characterization, material characterization, computational modeling, and data acquisition and controller development. The goal is to develop sufficient understanding of the induction heating process to control it more precisely, ensuring that parts are hardened to specification and that scrap is reduced.



In the induction hardening process, a magnetic coil heats the surface and near-surface of a part (in this case, a gear) to make it harder than the more ductile interior.

One of the research projects that may change ordinary automotive maintenance involves fluid monitors for engine oil. With today's technology, car owners change engine oil at set intervals (based on the calendar or miles traveled). However, they don't know the actual condition of the oil that they're changing (viscosity, level of contaminants, etc.), and therefore may be changing oil too often or not often enough.

Workers in Sandia's Microsensor Research and Development Department are working on in-situ monitors that will provide real-time information on oil condition. "We want to catch the oil at the appropriate time in its degradation cycle," says Richard Cernosek, one of the researchers on the project. "We want to know when it needs changing, but not change it so early that we increase environmental wastes." Project workers are adapting a quartz crystal microbalance sensor that measures the change in viscosity and the rate of particulate buildup in fluids. As the technology for monitoring engine oil advances, there may be further uses, such as checking engine coolant and other fluids.

The agreements with General Motors run from two-and-a-half to three years. In addition to the projects on induction hardening and oil monitoring, Sandians will be working on improved aluminum alloys, task analysis software, thermal spray technology, and materials selection software. This last task is a "knowledge-based" application (a software system that is broader-based than an expert system) aimed at making materials choices that are more environmentally aware.

These CRADAs and other agreements with U.S. automakers are moving Sandia into a new arena for transferring technology and expertise to U.S. industry. Sandia will also be an active player in the administration-backed agreement to create the U.S. super car, an 80-mile-per-gallon, environmentally friendly car for the 21st century. Defense technology at Sandia is now serving the broader goal of national economic competitiveness; helping the domestic auto industry is an important part of that effort.

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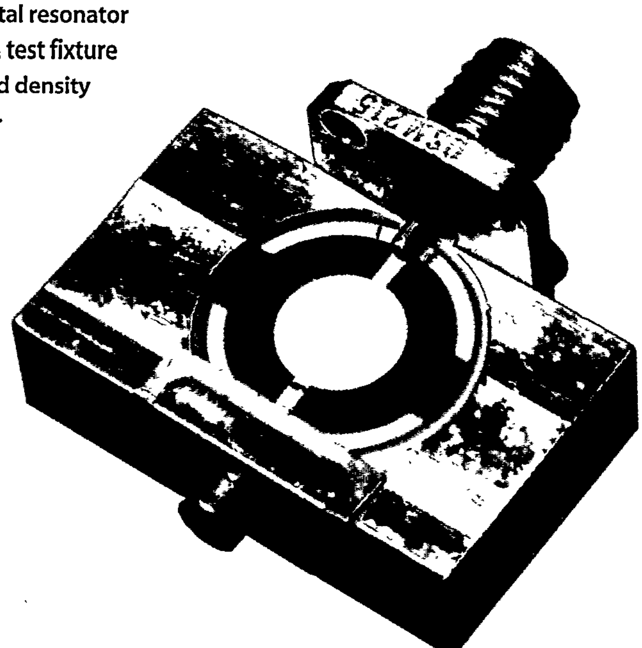
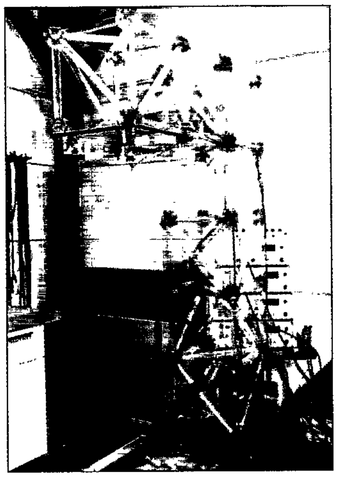
A quartz crystal resonator mounted in a test fixture monitors fluid density and viscosity.



good VIBRATIONS

Active control eliminates noise or unwanted motion



The benefits of vibration control on a structure can be studied and analyzed on a test platform such as this one in the Smart Structures Lab at Sandia.

Noisy trains, vibrating engines, chattering machine tools, trembling microchips on an assembly line—these and other items suffering from excessive noise or motion can be stabilized through a technique known as active vibration control.

Active control differs from conventional passive methods, such as a rubber damper between an engine and a frame. The rubber damper simply absorbs shock and vibration; it does not directly control the motion of the engine. Active control, however, generates a response to counteract the unwanted noise or vibration. Sensors in the active control system measure how much the engine is vibrating and send the information to a central processor, which directs actuators to apply forces on the engine and counteract the vibration.

The result: reduced vibration.

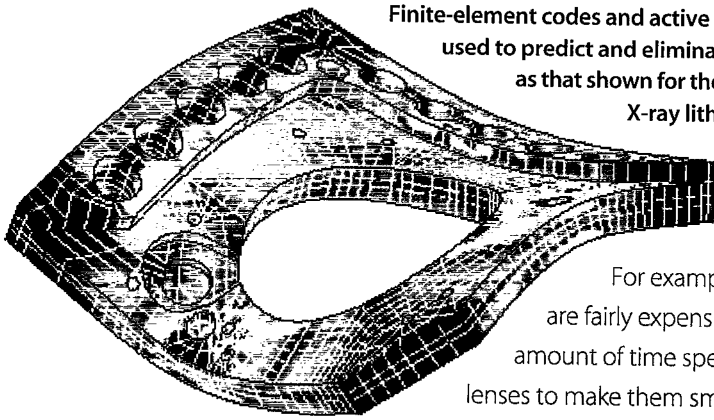
Luxury cars sometimes feature active control of interior noise. Sensors inside the car detect noise from the engine, for instance, and put out a signal through the speaker system to cancel the sound.

Sandia researchers are now investigating the same principle to minimize noise on the Bay Area Rapid Transit system in California, known as BART. They are instrumenting individual train cars and studying the resonances and acoustic response of the sounds generated. Eventually, active or passive control may be used to reduce the noise.

Sandia's expertise in this arena comes from work in advanced submarine technology for the Advanced Research Projects Agency, notes Sandia electrical engineer Bert Tise. A structure such as an airplane, spacecraft, or manufacturing device can be fitted with sensors that detect vibration and movement and with actuators that counteract the vibration or motion. Both sensors and actuators feed into a central processor.

The concept of active control has existed since the 1950s, but until the late 1980s, computer power and speed were inadequate to handle the complicated calculations needed to operate such systems.

Active control has many potential applications, such as stabilizing engine mounts, reducing machine tool chatter, grinding precision lenses, or manufacturing integrated circuits and flat-panel displays.



Finite-element codes and active control can be used to predict and eliminate vibration, such as that shown for the upper mirror of an X-ray lithography machine.

For example, optical lenses are fairly expensive because of the amount of time spent polishing the lenses to make them smooth. Typically, robots grind the lenses, but because the grinding tool vibrates, the resulting surface is not completely smooth and must be polished manually to its final smoothness after the lens is ground. "If we could stop the grinder from vibrating, the cost of a lens would be lower because it would require less polishing," says Tise.

Another application is photolithography of silicon wafers for integrated circuits. Currently, IC patterns are transferred onto silicon wafers by exposure to an energy source shining through a mask. Each time the wafer is moved between exposures, it vibrates, and the manufacturing process must slow down and wait until the wafer settles. With active control, photolithography would be faster and more stable, perhaps allowing for even finer, more closely packed circuits in microprocessors.

Sandia is now looking at transferring ARPA's active vibration control and processor technology to industry. One company is planning to repackage the processors to make them smaller. If active control systems become abundant enough to be economical, they might one day be used to quiet industrial coolers or mitigate earthquake shocks in buildings.

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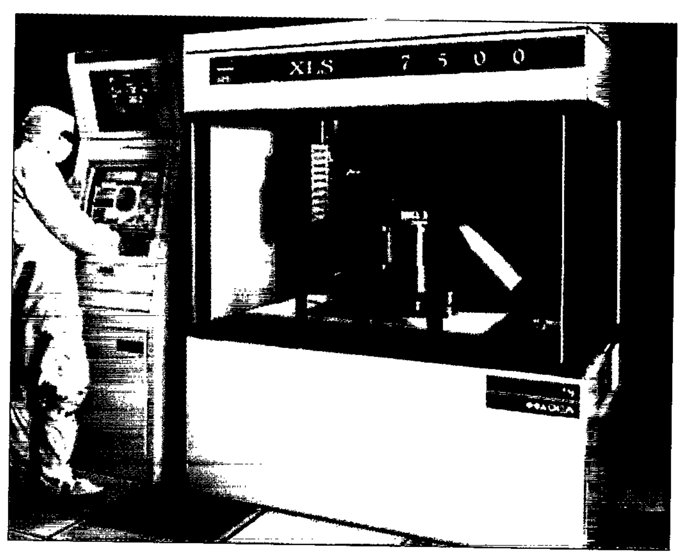

A researcher works on a commercial lithography machine, a microcircuit manufacturing device that can benefit from a Sandia-designed system that minimizes vibration.

Satellite-based information systems provide more than cable television

Sandia researchers are helping develop a transportation management system keyed to Geographic Information Systems, a technology that uses satellite signals to pinpoint a vehicle's location. Automobiles may one day be equipped with sensors and transmitters that can give their condition and location in an accident.

Safer transportation

It's not a very likely scenario, but not unthinkable, either: A school bus carrying 40 children and their teachers runs off a road in a remote part of the state. The wheels are damaged and the bus has to be towed.

Perhaps they are on their way to a game in another region, or returning from a nature hike. Depending on how remote their location, it could be several hours before anyone knows that something went wrong, let alone where the vehicle is located or what happened. Parents will be worried about their kids.

However, sophisticated communication techniques will soon bring modern technology to transportation's doorstep in the form of sensors, satellites, and state-of-the-art mapping that will allow rescue workers to track damaged vehicles and respond immediately to an accident.

This kind of technology has already been developed at Sandia with Energy Department support to protect vehicles carrying weapon components. Sandia has

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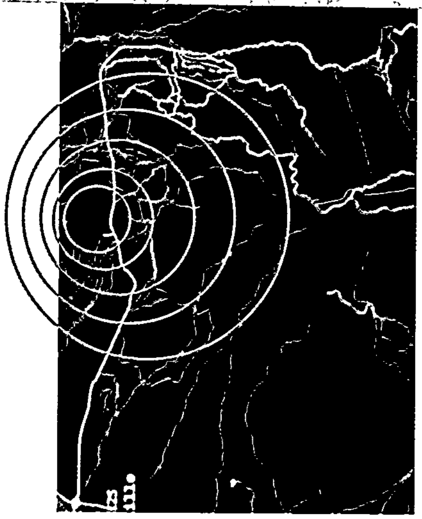

also been asked by New Mexico Gov. Bruce King to demonstrate how to use the technology to respond to an accident quickly and effectively. The demonstration will use a real bus with a real driver traveling through a remote area of the state.

On a much larger scale, the same technology is expected to be a key component of the Intermodal Surface Transportation Efficiency Act, a congressionally mandated program requiring all 50 states to improve the nation's infrastructure for moving people from one place to another. Overseen by the Transportation Department, the act seeks to improve pavement, bridges, safety, congestion, public transportation, and intermodal management.

The legislation requires automated traffic, highway, and emergency management systems to be in place by 1995 at the state and local levels; shared decision-making at national, state, and local levels; and a management approach that takes in all forms of transportation by land, air, or water.

To assist states in meeting these requirements, Sandia's Transportation Systems Center is developing a prototype system keyed to Geographic Information Systems, an emerging technology that uses satellite signals to pinpoint a vehicle's location within meters, as well as to relay critical information instantly to any point in the world. In the future, individual automobiles might even be equipped with sensors and transmitters that can give their condition and location in the event of an accident or if the car is stolen or the driver kidnapped, explains Sandia project manager Bob Cover.

In a separate cooperative effort that is backed with financial commitments from 40 states and endorsed by the Federal Highway Administration, Sandia researchers will embark on the largest GIS research project in the nation. Results will help states implement management systems mandated by the federal legislation.

Because of work done on vehicle security for the Energy Department, Sandia researchers can already combine road maps, utility maps, topographic maps, lists of emergency contacts, maps of waterways and airports, and other vital information on one computer screen. Sandia researchers continually update the maps based on satellite images, Federal Aviation Administration updates, or other sources of geographic information. There is so much data that "future computer systems will likely use high-capacity storage devices that hold pedabytes—1,000 million megabytes of data—and require high-speed networking between individual stations," says Cover.

A computerized data base can track the location and condition of any vehicle as its position is displayed on the screen. During a recent demonstration for visitors from the U.S. Coast Guard, a roomful of computer screens tracked convoys in New Mexico, Tennessee, Texas, Pennsylvania, and Colorado and a motorcade of VIPs in Washington, D.C. If one of the drivers were to take the wrong route, the computer would "blow the whistle." For security reasons, even detours are carefully monitored.

At the control center, the user can choose whatever level of detail is desired—showing only major highways, secondary roads, or even utility lines. For smaller-scale applications, specific data bases can be put at the user's fingertips at a single desktop workstation.

NONPROLIFERATION

With kid gloves

Protective containers help prevent dismantlement disaster

While the prospect of nuclear arms reductions promises to enhance the safety of all the world's inhabitants, dismantling nuclear warheads is not a simple matter. As weapons of mass destruction, they must be handled with great care.

To help meet this need, especially for weapons transported over long distances, the Energy Department has directed Sandia to design containers to protect nuclear weapons in the event of an aircraft crash and a subsequent fuel fire. The program supports nuclear disarmament and also protects the environment and avoids the cleanup costs that would accompany any dispersal of nuclear material.

These protective vessels, called Transportation Accident Resistant Containers, are designed to survive a minimum 225-feet-per-second impact on a hardened concrete target, such as a runway, followed by a 2-hour fuel fire of 1,800 °F. The containers must also protect warheads from shock loads that could potentially scatter nuclear materials. Sandia's extensive testing facilities make it possible to evaluate the effects of such conditions and design components to withstand them.

To date, Sandia has designed and tested three basic containers that can transport seven different nuclear weapons. "These weapons range from small artillery projectiles to large, lay-down bombs," says engineer Robert Monson, at Sandia's California facility.

Each vessel consists of an inner and outer container. The outer container is made of a thin, stainless steel skin, chosen for its great ductility, that can withstand considerable deformation without rupturing. Inside the container is a redwood material that can absorb considerable kinetic energy and provide thermal insulation. In extreme

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Robert Monson
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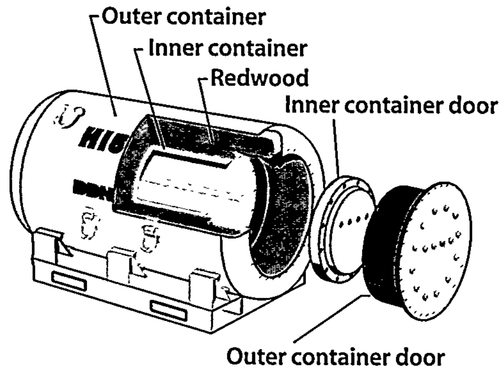


A protective container for carrying nuclear weapons (left) is subjected to intense fire at a Sandia test facility in Albuquerque, New Mexico. A cross section (above) shows protective layers that can withstand deformation and heat.

heat, as long as there are no large ruptures, the redwood will char instead of burn because of a lack of oxygen, continuing to provide thermal protection.

Inside the redwood layer is a thick, aluminum inner container designed to protect warheads from possible punctures and deformation, and serve as a backup container to prevent dispersal. Special inserts designed to fit each weapon limit shocks during transportation and provide added protection in the event of a crash.

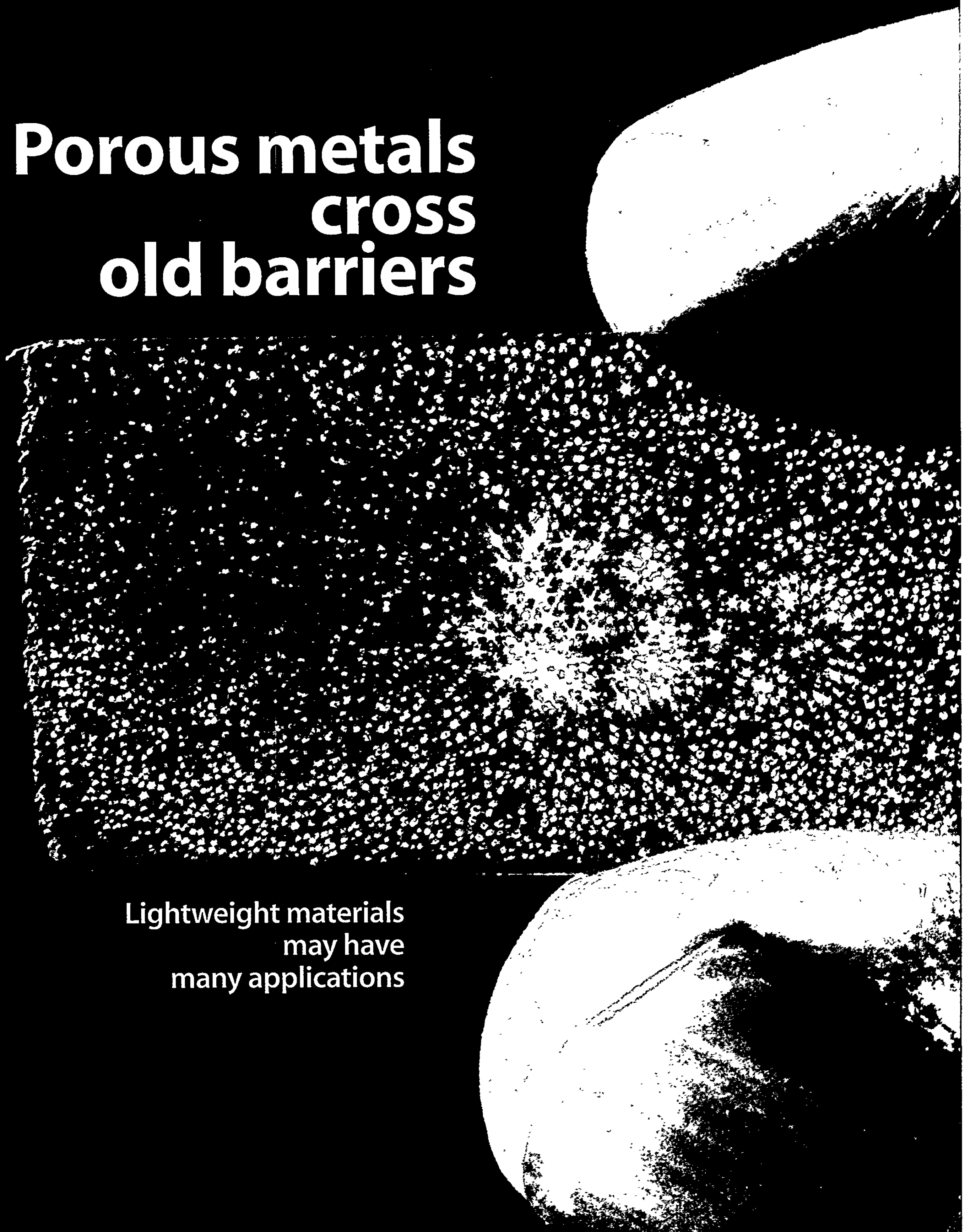
Three-dimensional computer modeling, one of Sandia's major areas of expertise, simulated many of the accident scenarios and reduced the time and cost that would be required to conduct full-scale impact tests.

Large, finite-element models were used to predict the response of the container and the warhead. These calculations predicted the behavior of the outer stainless steel skin, the impact magnitude at various velocities, the effect of various container orientations, and even the behavior of door bolts joining container parts.

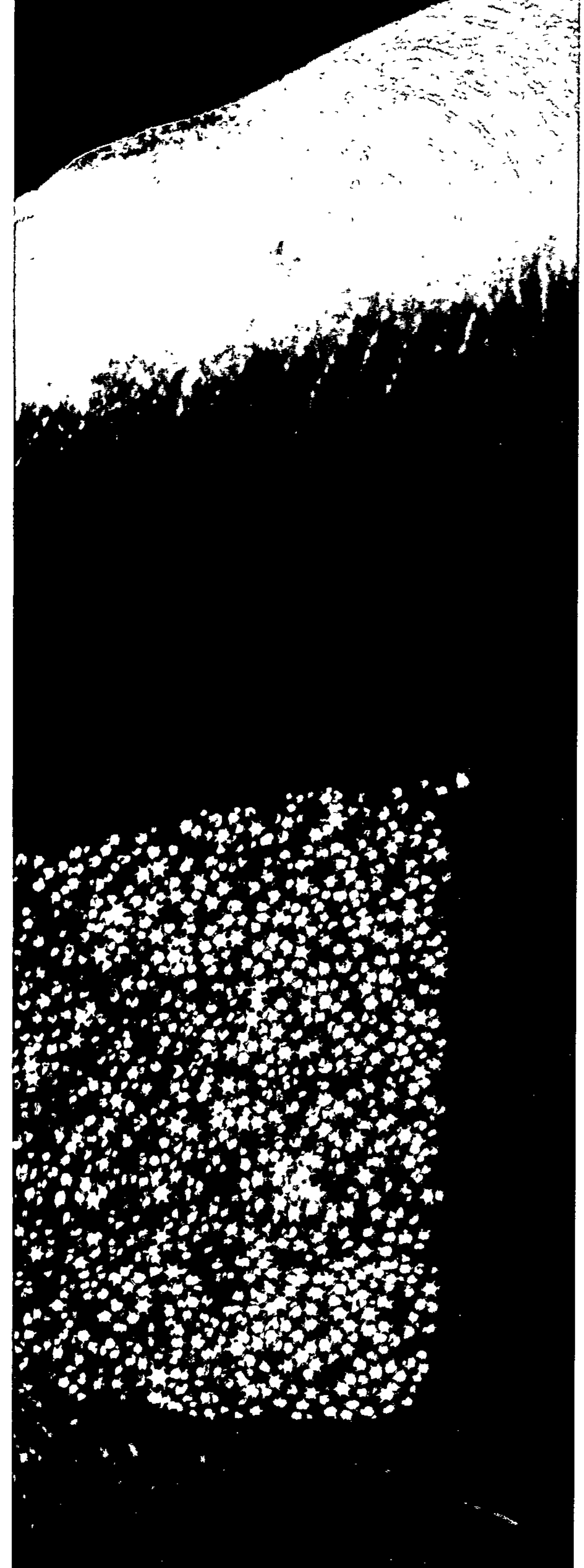
Such calculations enabled engineers to optimize the design of the inserts for the weapons being transported and maximize the accident conditions each warhead could survive, says Sandia engineer Mike Chiesa. The computer models also calculated the response of the redwood shielding and the effect of the concrete target or runway on the crash vehicle and its cargo. In addition, actual testing of components, such as drop tests, burn tests, and vibration tests, validated the predictions of the computer models.

Sandia first began designing Accident Resistant Containers for the Energy Department to prevent dispersal of plutonium from warheads in the early 1970s. In the mid-1970s, Sandia designed a smaller container to be carried on helicopters. By the late 1980s, Sandia began modifying and converting container designs to accommodate other weapons. Today, the containers accommodate the W79, W70, W48, B57, and B61 warheads. Soon, the containers will also accommodate the W62 and W78 warheads.

Porous metals cross old barriers



Lightweight materials may have many applications



As the countries of the former Soviet Union become more open to trade, travel, and communication, the technologies developed during decades of conflict and competition with the West are becoming more widely known. At the Dnepropetrovsk Metallurgical Institute in the Ukraine, a special class of porous metals has been developed for many applications calling for light weight and high strength. Sandia will now fabricate and test some of these materials to gain a basic understanding of them and evaluate them for possible use in U.S. industry.

The project calls for construction of a furnace at Sandia to produce the porous metals. "These lightweight, porous metals have tremendous potential for applications in U.S. industry," says Frank Zanner, of Sandia's Liquid Metal Processing Department. "Our job at Sandia will be to validate the claims made about them and eliminate the risks to industry." Information about the porous metals, which Ukrainian metallurgists call GASAR materials, will be shared with the U.S. Specialty Metals Processing Consortium. Sandia conducts research in collaboration with the SMPC, which aims to increase U.S. competitiveness in the world specialty metals market.

The GASAR metals are cast under high pressure to create their unique porosity. While their porosity gives them light weight, they are reported to possess great structural integrity, resulting in high strength and rigidity. The porous metals retain physical properties that allow metal forming, cutting, welding, bending, and machining. "These metals were the cornerstone of the Soviets' rocket program," says Mike Maguire, lead researcher for the project at Sandia. In FSU countries, the materials are used commercially for chemical filters, bearings, ceramic supports in rocket and jet engines, lightweight panels for space uses, and oxygenators for water purification.

Dnepropetrovsk scientists will provide plans for a furnace to create the special metals; these plans will be compared to Sandia-developed plans prior to furnace construction. The agreement with the Ukrainians also calls for Sandia to provide lab equipment and funding to Dnepropetrovsk researchers, in addition to licensing fees for the metal-making process. The licensing agency is DMK TEK Inc., a company jointly owned by U.S. and Ukrainian partners.

"There is a lot of interest in these materials among U.S. companies," says Maguire, "but until they see someone in this country make the materials and test them, there is also uncertainty." The Dnepropetrovsk Metallurgical Institute will research three different alloys and present the results to Sandia and the SMPC. This work will guide U.S. efforts to duplicate these materials. The project is one among many that continue to show the benefits of scientific and technical cooperation between old adversaries.

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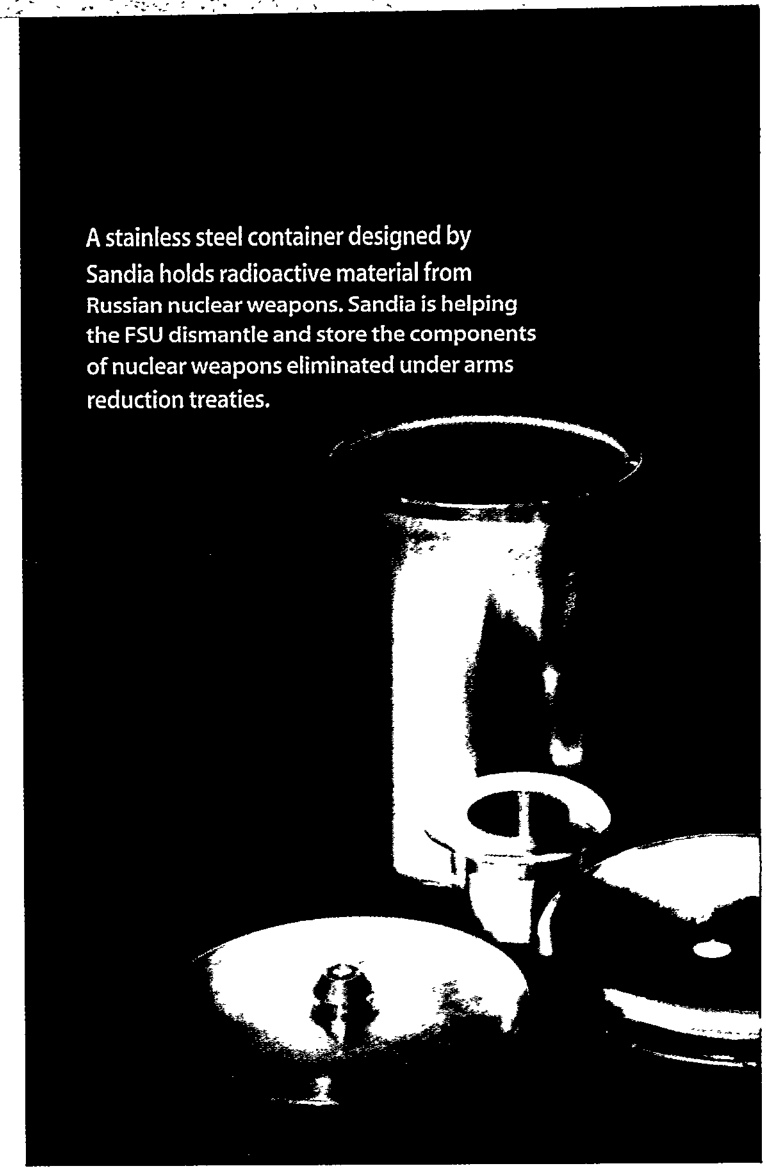
Liquid Metal Processing

Old enemies, new partners

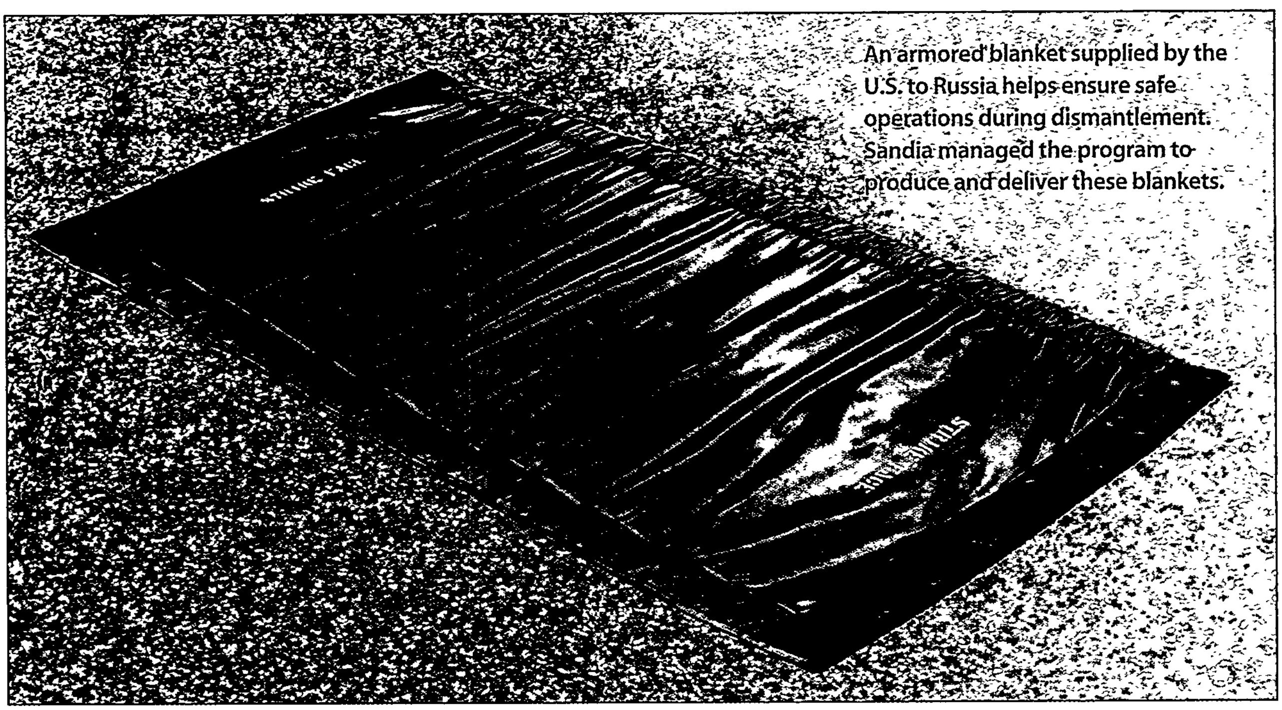
Working with the FSU to ensure nuclear safety



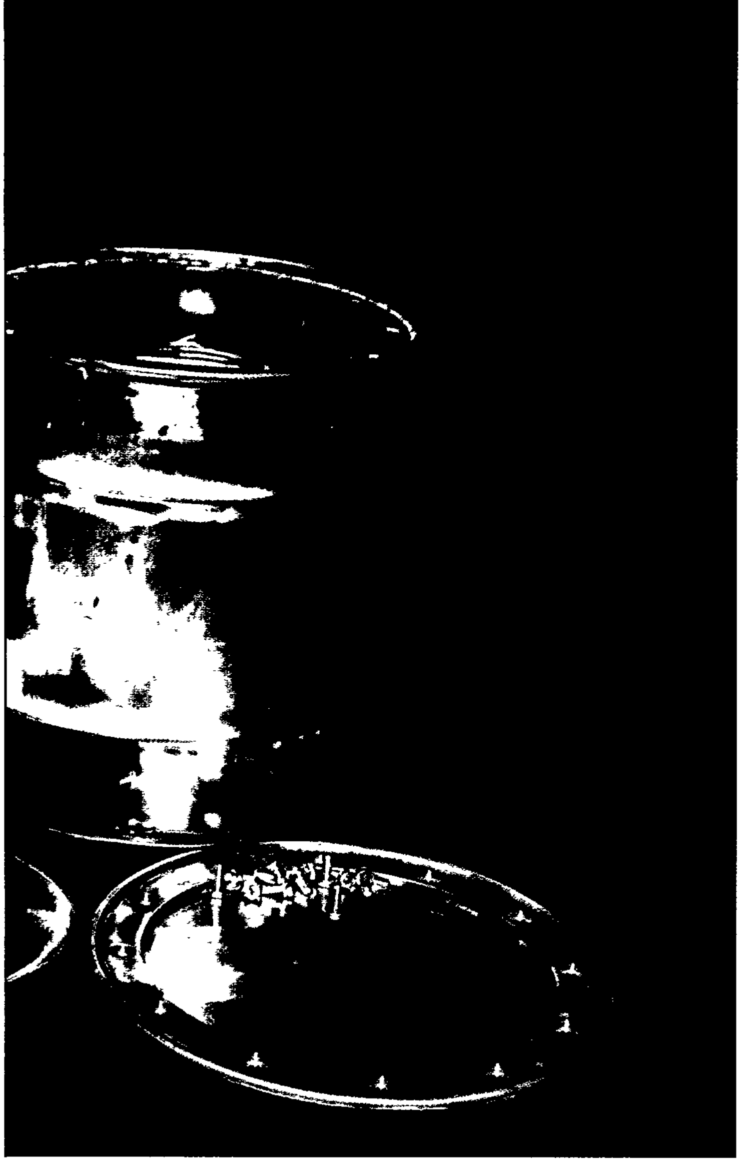
A stainless steel container designed by Sandia holds radioactive material from Russian nuclear weapons. Sandia is helping the FSU dismantle and store the components of nuclear weapons eliminated under arms reduction treaties.

When the strategic arms reduction treaties were signed with the Soviet Union, nobody in the U.S. foresaw the imminent collapse of the Communist government and the emergence of several nations with nuclear weapons on their soil. Now Sandia is working with the former Soviet Union (as are other U.S. labs and government agencies) to help ensure that, as the treaties are implemented, safety and accountability are maintained over the scattered FSU stockpile.

Several projects are under way to help the FSU (primarily Russia) transport weapons safely and maintain control over all nuclear weapons. In one effort, 2,500 armored blankets were delivered to Russia to provide small arms protection during



An armored blanket supplied by the U.S. to Russia helps ensure safe operations during dismantlement. Sandia managed the program to produce and deliver these blankets.



operations associated with dismantlement. Sandia managed this work and received a commendation from DOE for coming in ahead of schedule and under cost.

Sandia engineers are also designing and testing containers for radioactive material from Russian weapons to ensure safe storage and transportation. The Defense Nuclear Agency will procure the containers, and Sandia will provide quality evaluation for fabrication processes. Sandians are involved in the design of a facility to store radioactive materials after they are removed from weapons. They are also involved in other projects to ensure that the reduced Russian stockpile will be safe and secure.

"We want to make sure that they know where everything is all the time," is the way Dave Nokes puts it. Nokes is manager of Sandia's Surety Program Office and has been involved in many of the projects with the FSU. His words reflect the view that, with the reduced tensions between the U.S. and the FSU, the greatest nuclear danger in this area is the theft or diversion of nuclear weapons in the new states of the FSU.

To ensure that this does not happen, Sandians have been working with Russian counterparts on transportation and surety issues. "It is in our interest to diminish some of the folklore on their side about what we're like, and diminish the folklore on our side about them," Nokes said. Sandia weapons experts have visited some of the Russian weapons facilities that were impenetrable a few years ago and are proposing projects with Russian labs to keep Russian weapons personnel employed.

As cooperation continues between the two former enemies, Sandians will be helping Russians keep their weapons under firm control, accountable to treaty requirements, and out of the hands of terrorists.

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AWARDS and PATENTS

Awards

Professional society and prestigious awards

Mike Cieslak	American Welding Society Professor Masubuchi/Shinso Corporation Award
Robert Graham	American Physical Society 1993 Shock Compression Award
Walter Herrmann	Academy of Engineering fellow
Gary Kellogg	American Physical Society fellow
Al Narath	American Association for the Advancement of Science fellow
Gordon Osbourn	American Physical Society International Prize for New Materials
Carl Peterson	American Institute of Aeronautics and Astronautics fellow

Other prestigious awards

Keith Almquist	Central Intelligence Agency National Intelligence Meritorious Unit Citation for his role as a member of the Nuclear Weapons Security and Logistics Working Group
Carol Ashby David Ginley Jon Martens Tom Plut	R&D 100 Award for development of a family of water-based chelating etches for the photolithographic processing of metal-oxide thin films used in the development of microelectronic devices
Ted Blacker Ray Meyers John Biffle Michael Stephenson (BYU) Roger Cass (BYU)	R&D 100 Award for development of a mesh-generation algorithm called "paving" that enhances computer-aided design of numerous industrial products
Don Cook	Fusion Power Associates 1993 Leadership Award
Rich Diver (SNL) Cummins Power Generation, Inc. Sunpower, Inc. Thermacore, Inc.	R&D 100 Award for development of a solar parabolic dish system for converting sunlight into electricity
David Haaland David Melgaard Thomas Niemczyk (UNM)	Semiconductor Research Corporation, Durham, NC, 1992 Technical Award of Excellence for research of methods for measuring the quality of microelectronic circuits using infrared spectroscopy and chemometrics
Bob Hughes Jose Rodriguez Wayne Corbett	R&D 100 Award for development of a microsensor that can detect hydrogen in a wide array of industrial applications
Paul Klarer Jim Purvis Kent Biringer	*Design Engineering* magazine monthly international design competition with the Robotic All-Terrain Lunar Exploration Rover (RATLER)
Mike Maguire	American Welding Society Charles H. Jennings Memorial Award

Sandia Labs	Society of Manufacturing Engineers Citation for Economic Development
Annette Sobel	Aerospace Medical Association 1993 Julian E. Ward Memorial Award
Jim Sweet **Dave Peterson** **Melanie Tuck**	R&D 100 Award for development of a family of integrated circuits used to test semiconductor assembly and packaging processes
Larry Teufel (Sandia) **Douglas Rhett and** **Helen Farrell (Phillips Petroleum)**	1993 U.S. National Committee for Rock Mechanics Case History Award for work described in the paper "Effect of reservoir depletion and pore pressure drawdown on in-situ stress and deformation in the Ekofisk Field, North Sea"
Margie Whipple	Society of Women Engineers Distinguished New Engineer Award for 1993

DOE/DoD awards

Bob Bradley	Secretary of Defense Federal Advisory Committee on Nuclear Failsafe and Risk Reduction (FARR) Award for Excellence for contributions to FARR's Remote Destruct Study Group
Dick Brodie	Department of Energy Distinguished Associate Award for distinguished and unique contributions to the surety of nuclear weapons and nuclear weapon systems, and for outstanding leadership in an area of utmost importance to the security of the United States
Dick Craner	1993 Department of Energy Classification Award for Excellence
Mark Dickinson	Secretary of Defense Federal Advisory Committee on Nuclear Failsafe and Risk Reduction (FARR) Award for Excellence for contributions to FARR's Positive Control Materials and Devices Study Group
Wil Gauster	Department of Energy Distinguished Associate Award for outstanding contributions to the nation's fusion energy program, particularly in the areas of fusion plasma materials interactions and high heat flux components, and continuing efforts to further international collaboration in fusion
Orval Jones	Department of Energy Distinguished Associate Award for distinguished and unique contributions to nuclear weapon safety and security and for outstanding leadership in establishing programs of utmost importance to the security and economic well-being of the United States
Al Narath	Secretary of Energy Outstanding Contractor Manager Award for 1992
Heinz Schmitt	Secretary of Defense Federal Advisory Committee on Nuclear Failsafe and Risk Reduction (FARR) Medal for Outstanding Public Service for serving as Chairman of FARR's Technology Working Group from 5/91 through 10/92
Wendell Weart	Secretary of Energy Outstanding Contractor Program Manager Award for 1992

Patents

Advanced motor-driven clamped borehole seismic receiver
B. P. Engler, G. E. Sleefe, R. P. Striker
Patent #5,189,262

Apparatus and method for laser velocity interferometry
L. L. Bonzon, O. B. Crump Jr., P. L. Stanton, W. C. Sweatt
Patent #5,245,473

Apparatus and method for measuring and imaging surface resistance
J. S. Martens, V. M. Hietala, G. K. G. Hohenwarter
Patent #5,239,269

Apparatus and method to enhance X-ray production in laser-produced plasmas
A. L. Augustoni, J. B. Gerardo, T. D. Raymond
Patent # 5,175,757

Chloromethyl chlorosulfate as a voltage delay inhibitor in lithium cells
F. M. Delnick
Patent #5,202,203

Crystalline titanate catalyst supports
R. G. Anthony, R. G. Dosch, B. Tex
Patent #5,177,045

Digitally controlled distributed-phase shifter
V. M. Hietala, S. H. Kravitz, G. A. Vawter
Patent #5,237,629

Electrically controlled polymeric gel actuators
D. B. Adolf, D. J. Segalman, M. Shahinpoor, W. R. Witkowski
Patent #5,250,167

Hybrid sol-gel optical materials
J. M. Ziegler
Patent #5,204,381

Method for forming hermetic coatings for optical fibers
T. A. Michalske, R. R. Rye, W. L. Smith
Patent #5,246,746

Integrated optical tamper sensor with planar waveguide
R. F. Carson, S. A. Casalnuovo
Patent #5,177,352

Method and apparatus for acoustic plate mode liquid-solid phase transition detection
D. S. Blair, G. C. Frye, R. C. Hughes, S. J. Martin, A. J. Ricco
Patent #5,187,980

Method of producing strained-layer semiconductor devices via subsurface patterning
B. W. Dodson
Patent #5,225,368

Method for simultaneous measurement of mass loading and fluid property changes using a quartz crystal microbalance
V. E. Granstaff, S. J. Martin
Patent #5,201,215

Method and split-cavity oscillator/modulator to generate pulsed particle beams and electromagnetic fields
P. D. Coleman, M. C. Clark, B. M. Marder
Patent #5,235,248

Micromachined resonator
N. A. Godshall, D. R. Koehler, A. Y. Liang, B. K. Smith
Patent #5,198,716

Multiple-frequency acoustic wave devices for chemical sensing and materials characterization in both gas and liquid phase
S. J. Martin, A. J. Ricco
Patent #5,235,235

Planar photovoltaic solar concentrator module
C. J. Chiang
Patent # 5,167,724

Process for making solid state radiation-emitting composition
C. S. Ashley, C. J. Brinker, S. T. Reed, R. J. Walko
Patent # 5,240,647

Quantitative method for measuring heat flux emitted from a cryogenic object
R. V. Duncan
Patent # 5,193,909

Reflection mass spectroscopy technique for monitoring & controlling composition during molecular beam epitaxy
T. M. Brennan, B. E. Hammons, J. Y. Tsao
Patent # 5,171,399

Sequencing and fan-out mechanism for causing a set of at least two sequential instructions to be performed in a dataflow processing computer
V. G. Grafe, J. E. Hoch
Patent #5,226,131

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