SAND 97-0958

SANDIA ACCOMPLISHMENTS

Sandia National Laboratories

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SAND97-0958

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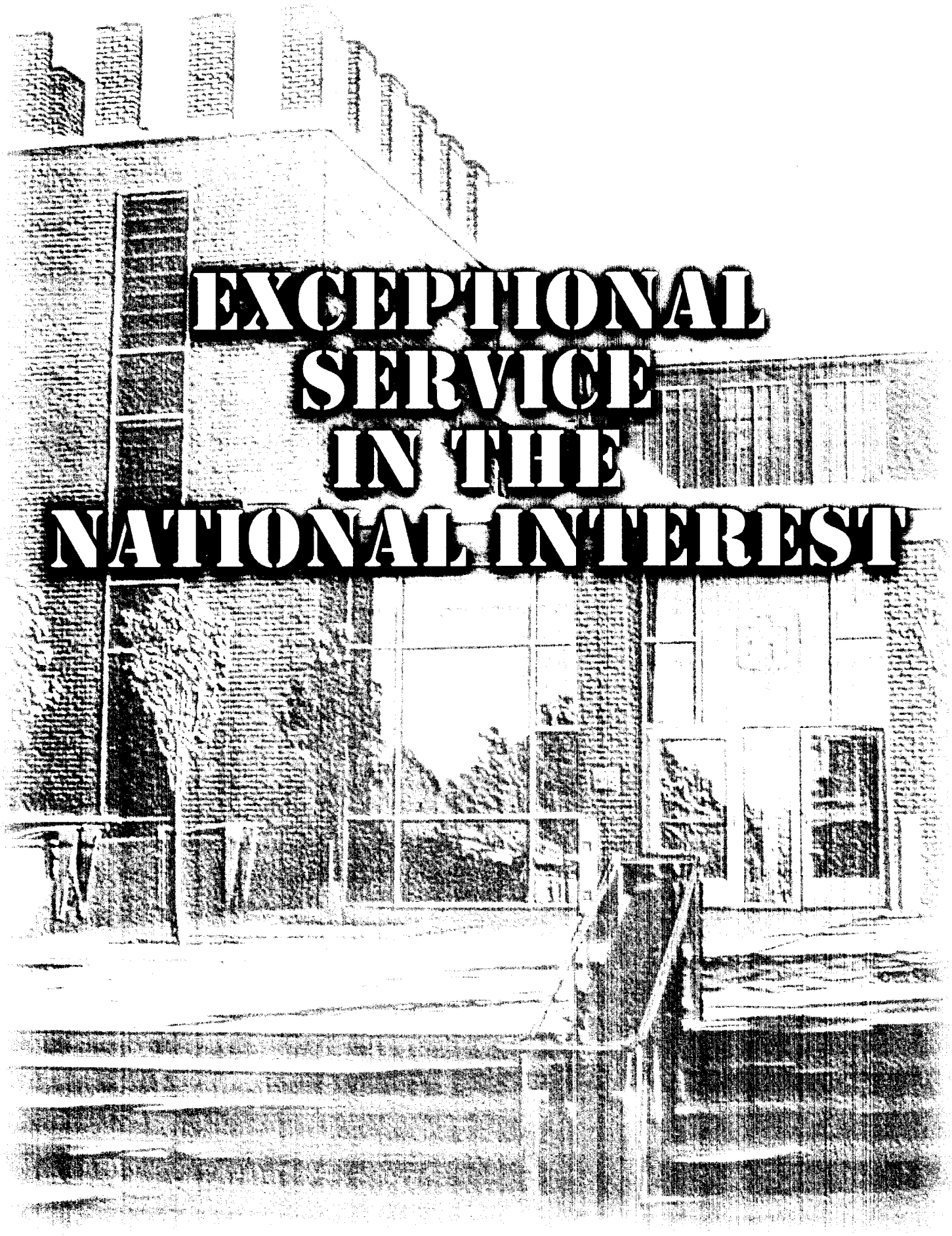
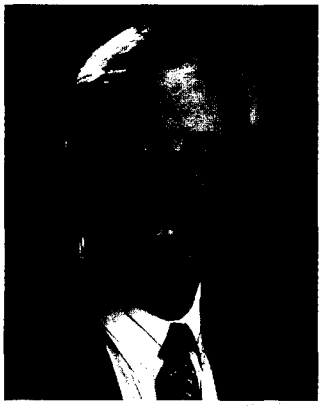

EXCEPTIONAL
SERVICE
IN THE
NATIONAL INTEREST

SANDIA ACCOMPLISHMENTS

To our readers:



When asked about his satisfaction as a customer of Sandia, one industrial leader volunteered the observation that he had worked with most of the national laboratories and in his opinion, "Sandia is unquestionably the best at application of science and technology."

When I first looked through the list of 1996 Labs Accomplishments, the accuracy of that customer's view of Sandia seemed apparent. We have produced an impressive list of achievements, the vast majority of which represent applications of science and technology to solve problems. Our applications serve the needs of internal customers as well as external customers (sponsors).

We produced a number of accomplishments that "made headlines" across the nation and in the international media. Foremost among these were the operation of the world's most powerful computer—the teraflops machine, the production of megajoules of X-rays using z-pinches, and the creation of silicon micromachines. With this came a large profusion of less well publicized but still very important breakthroughs—from the development of new sensors to the creation of new software systems.

Present in this year's list are also a number of reengineering accomplishments to make our internal processes simpler and cheaper.

I urge you to read the entire list, with a view toward how these accomplishments—both technical and administrative—might benefit you. Please join me in congratulating all the men and women whose dedication and work produced these advances.

C. Paul Robinson
Labs Director and President

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COMPUTATION

TERAFLOPS—One trillion calculations per second.

Demonstration of New World Record Supercomputer Performance

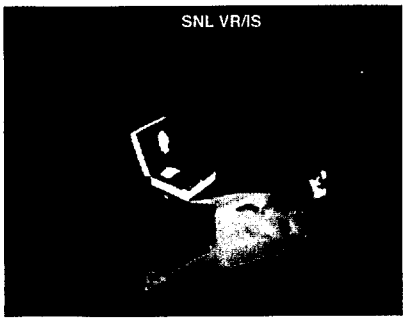
Sandia's supercomputer research and development project with Intel smashed the trillion-operations-per-second (teraflops or TFLOPS) hurdle on December 4, 1996, setting a new world record. The massively parallel LINPACK program (a standard benchmarking program) ran at 1.07 teraflops on 75 percent of the ASCI (Accelerated Strategic Computing Initiative) TFLOPS supercomputer at Intel's integration facility in Oregon. This record leapfrogs the 368 gigaflops (billions of operations per second) record set by a Hitachi system in Japan earlier in 1996, which itself beat Sandia/Intel's 283 gigaflops mark set in 1995. The record also marks the first milestone toward DOE's goal of attaining 100 teraflops by 2005. Sandia expects to set a new record of 1.4 teraflops when its fully configured massively parallel supercomputer is operational later this spring.

3-D Terrain Models from SAR Data

Scientists have combined Sandia-developed synthetic aperture radar (SAR) technology with a commercially available laser lithography process to produce extremely accurate three-dimensional topographic models. The technique starts with an aircraft equipped with SAR equipment. As it flies, the aircraft emits pulses of energy from an attached antenna. These pulses (which can be emitted day or night or even through clouds) hit the ground and are reflected back up to the antenna. The information that the returning pulses deliver is combined to form an accurate image of the landscape. These topographic details are combined with a laser lithography rapid prototyping process to "grow" three-dimensional models from a bath of liquid epoxy. The three-dimensional maps will have military applications such as precision-guided munitions, and may have an enormous number of commercial uses.

Virtual Reality Emergency Medical Training

VR-MediSim is a virtual reality system developed by Sandia's Virtual Reality / Intelligent Simulation Team to train emergency medical personnel. Medics are immersed in a virtual world where they are confronted with real-life casualty situations. The integration of VR-MediSim with DIS (distributed interactive simulation, a type of military simulation) provides for the first time an environment that helps train combat medics in the midst of action under battlefield conditions, just as pilots in the armed forces are trained with flight simulators. In addition to this medical training tool, the Sandia-developed virtual



VIRTUALLY REAL—Sandia-developed VR-MediSim virtual reality medical training simulation.

reality infrastructure is being used to develop prototype training systems for combating terrorism and for teaching nuclear weapons maintenance.

New Computer-Designed Optical Memory Material

Computer-aided design methods have been used to synthesize optical memory properties into porphyrin-based materials for ultra-fast, ultra-high-density optical memory devices such as computer disk drives. Conventional porphyrins cannot be used for memory storage, but the new porphyrins—computer designed and synthesized in collaboration with researchers at the University of California and Washington University—can be used for optical memory applications. Computer-guided synthesis avoids traditional trial-and-error methods of discovering new materials. Computational predictions for the new porphyrins were validated by measured improvements in the optical and magnetic properties. Memory retention times of porphyrins were improved 500-fold, and 30-picosecond memory-state switching times (which are about 100 times faster than those of conventional devices) were achieved. Identified pathways for further improvements are being pursued.

Mobile DoD Command Centers

Major Department of Defense Command Centers would be vulnerable to attack in the event of a nuclear war, if not for a suite of 40-foot tractor trailers equipped to serve as back-up command centers. Sandia modifies, installs, and retrofits the equipment for these "offices on wheels," called Commander-in-Chief Mobile Alternate Headquarters. These mobile centers contain communication and message-handling equipment and anything else needed to allow them to be deployed and survive if needed. Besides installing, maintaining, and updating the equipment in 1996, Sandia delivered a new 40-foot Multimedia Communications Shelter trailer to the NORAD/USSPACECOM Mobile Consolidated Command Center. Sandia is also providing support for a "Future Look" analysis of the new Commercial-Off-The-Shelf networking technology to be installed into these Mobile Alternate Headquarters to maintain modern equipment capability.

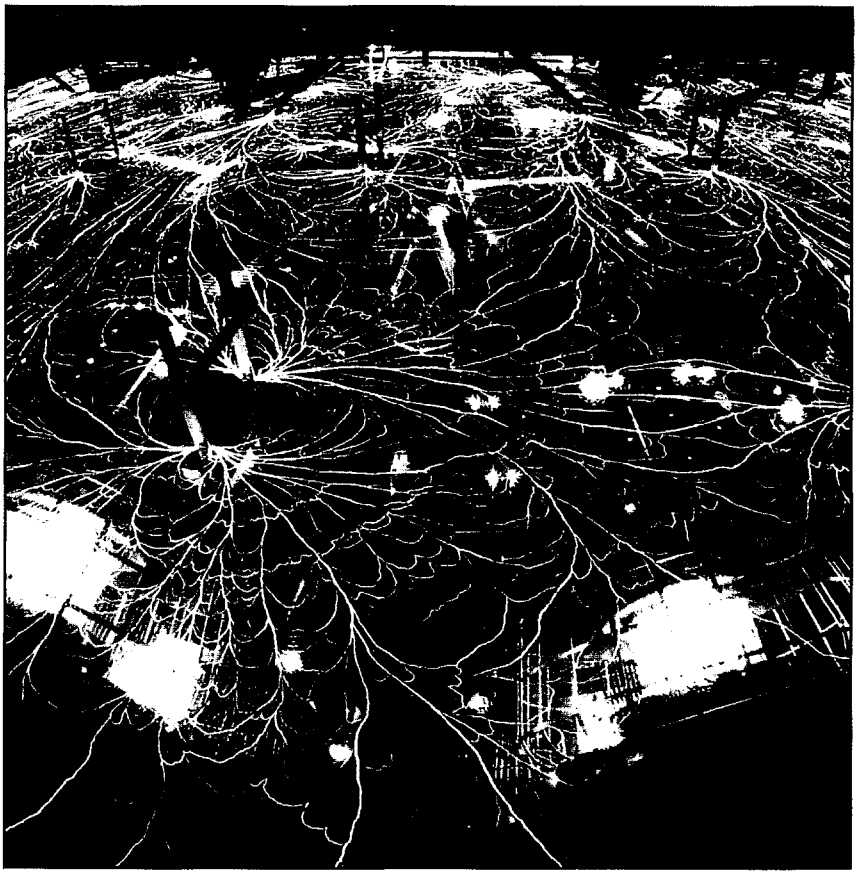
New Parallel Algorithm for Contact Detection

Crash dynamics simulations are essential to a safe nuclear weapon stockpile, to Sandia weapon upgrade programs, and to the American auto industry. Previous attempts at large-scale crash dynamics simulations were unsuccessful, for lack of a good algorithm that could simulate nonlinear, large deformations (as experienced in some nuclear weapon environments and car crashes) on a massively parallel computer. In a major breakthrough, Sandia researchers developed a scaleable decomposition algorithm for parallel computers that enables complex crash dynamics simulations of problems of unprecedented complexity. ("Scaleable" means the computer is running at maximum efficiency by equally using a large number of its processors to solve a problem. "Decomposition" means that the processors' workloads are evenly distributed, which is necessary to the success of the algorithm.) Crash dynamics events unbalance the processors, which is the obstacle the new algorithm had to overcome. This technology will be used to simulate the dynamics of weapons such as the B61-11 penetrator and the B61-3, 4, 10 laydown bomb.

PULSED POWER

Faster Communications with New ATM Router

A team of Sandia communications specialists increased the speeds of the corporate computer network by using new asynchronous transfer mode (ATM) technology. ATM was used to interconnect Sandia's backbone routers, the networking devices that allow computer users to leave their local networks and link with others on the corporate network. Communicating on Sandia's corporate network used to require several hops through routers in the backbone to connect to any other computer. But Sandia's new ATM router backbone requires only two hops to reach its destination. The ATM switch increased the bandwidth (with individual link rates of 155Mbps), eliminating constriction points and allowing more data to be transmitted through the network. At the same time, Sandia, Intel, and GigaNet collaborated to create the first ATM interface for the Intel Paragon, operating at 622Mbps. This interface allows for very high-speed communications between two Paragon computers, creating one virtual machine that solves bigger problems than is possible with two separate machines. The ATM interface received an *R&D 100* Award for its innovative approach to high-performance computer communications.



Z-PINCH BREAKTHROUGH—Sandia's pulsed power team, using the Labs' PBFA-Z (Particle Beam Fusion Accelerrator z-pinch configuration), has produced record high bursts of energy, far exceeding energy bursts such as the one pictured above on the PBFA-II, the predecessor to the z-pinch version.

Record-Breaking X-Ray Power Generation

Sandia's Particle Beam Fusion Accelerator (PBFA) II was renamed PBFA-Z when it was converted into a z-pinch driver, a type of generator that rapidly delivers large amounts of electrical energy to objects smaller than a centimeter. This creates extreme conditions of matter that are normally found only in unusual places such as stars, nuclear explosions, and supernovae. PBFA-Z generated 20 million amperes in 100 billionths of a second with a peak electrical power of 60 trillion watts. It has produced more than

1.5 million joules of X-rays at a peak power greater than 150 trillion watts of radiation. To put this in perspective, for 100 billionths of a second, PBFA-Z generates 85 times the total electrical power generating capacity of the U.S. PBFA-Z will provide an intense X-ray source for weapon physics, astrophysics, and atomic physics. Sandia completed the mechanical and electrical design, mechanical modifications, and initial pulsed power testing in 1996.

Materials Analysis with Saturn Accelerator

Newly developed laser-coupled fiber-optic sensors and a high-sensitivity Doppler interferometer system were developed by Sandia's Explosive Projects & Diagnostics Department to perform detailed analyses on materials "shocked" by high-energy X-ray emissions. (The Doppler effect employed in this system is the optical equivalent to the phenomena of the pitch change of a car's horn as it passes by.) The intense X-rays, produced by Sandia's Saturn accelerator, enter a test material (target) as a nanosecond-pulse of energy and create a shock wave that dynamically changes the density of the target. The material properties, X-ray duration, and intensity all have an effect on the way the Doppler-shifted laser light occurs. A transparent "window" material is bonded to the target, which allows the fiber-optic sensor to focus the laser light at the target-window interface. The X-ray-induced shock imparts a Doppler shift in the frequency (pitch) of the reflected light, which is collected and routed to the interferometer system for analysis. The new radiation-resistant sensors and analyzer, which measure the distorted laser light, are nearly immune to the radiation effects that plague electronic-based sensors. Findings from these experiments should help determine a material's response to a nuclear explosion and also help scientists develop new materials for use in related programs such as inertial confinement fusion research.

Radiation-Resistant Electronic Systems

The ability of weapon electronic systems to perform in high-radiation environments has been dramatically increased by a joint effort of Sandia's Radiation Sciences Program and the U.S. Army Space and Strategic Defense Command. The new "no-upset" electronic system is designed to operate during radiation events, as opposed to the previous "circumvention" system, which would power off and then reboot when it detected radiation. Improved system designs using radiation-hardened integrated circuits developed by the No-Upset Electronics Technology Program allow the new system to function in radiation levels that are up to 1,000 times higher than circumvention levels for previous systems.

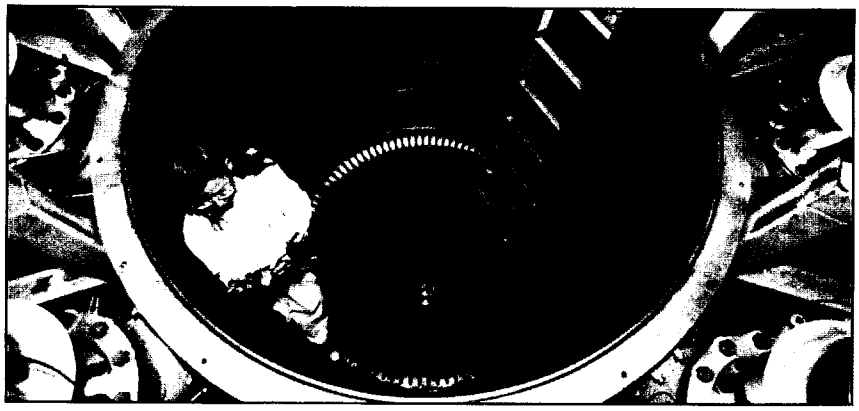
Nuclear Stockpile Verification with Advanced Hydrodynamic Radiography

Because of the ban on underground nuclear weapon testing, the U.S. needs another way to verify the reliability and safety of nuclear weapon primaries in the stockpile. The solution lies in benchmarking the evolving weapon design codes—running on the high-speed Accelerated Strategic Computing Initiative (ASCI) platforms—with improved-resolution experimental measurements of nonnuclear (simulated pit) implosions. The technology necessary to characterize these implosions is called Advanced Hydrodynamic Radiography (AHR) and represents a significant step beyond any demonstrated system. In a national program, the three weapons labs (Sandia, Los Alamos, and Lawrence Livermore) are pursuing different approaches to AHR, and DOE will select the most effective technology in FY 2000. Sandia has demonstrated a unique, compact, inexpensive approach that draws on its pulsed power expertise: Researchers are

turning down the raw power of the SABRE and HERMES-III accelerators, and then focusing the particle beams to produce extremely small (one-millimeter-sized) and bright (1,000 rads at a distance of one meter) X-ray sources in 50 billionths of a second. These X-rays image the weapon as it implodes to reveal any minute, yet critical, imperfections.

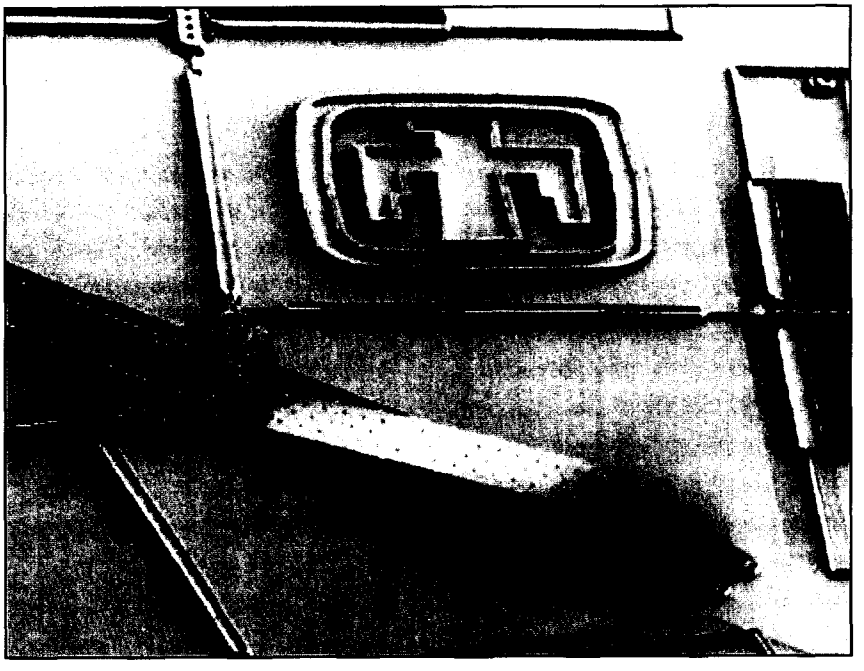
Record-Breaking X-Ray Power from a Z-Pinch Plasma

The X-ray power radiated from a z-pinch plasma dramatically increased to more than 80 trillion watts. (A z-pinch plasma is an extreme condition of matter produced by the Saturn pulsed power accelerator, which rapidly delivers large amounts of electrical energy to objects only about two centimeters across.) This peak radiation power level is nearly four times the peak electrical power delivered by the accelerator alone, and was produced with an overall energy efficiency of approximately 13 percent. The intense X-ray source is generated by accumulating electrical energy in a capacitor bank over minutes, then releasing the energy compressed in time and space so that an electrical current pulse is driven through a very small volume where the load is located. The load could be a 1.75-centimeter-diameter cylindrical array of very small wires, each about 0.005 of a millimeter in diameter. The current heats and ionizes the wires, forming a plasma, which implodes and in turn emits a large percentage of its energy as X-rays. This breakthrough was made possible by new insights into the dynamics of z-pinch implosions and opens up new research opportunities in the areas of inertial confinement fusion and weapons physics.



SATURN ACCELERATOR—A Sandian removes volt monitors from the center section of the Saturn pulsed power accelerator following a test shot. During 1996, the X-ray power radiated from a z-pinch plasma was dramatically increased to more than 80 trillion watts using the Saturn pulsed power accelerator.

ELECTRONICS, PHOTONICS, AND MICROMACHINES



MICROMIRROR— Each gear tooth of this optical mirror is about the size of a red blood cell.

Electromechanical "Systems-on-a-Chip"

Micromachines, or microelectromechanical systems—some as small as the diameter of a human hair, with features as small as 1/100 the diameter of a hair—have been produced by applying the same microfabrication techniques used to manufacture integrated circuits. These techniques are based on depositing and patterning thin films to create multiple layers. The end result is a tiny, three-dimensional micromachine (such as a gear) that originated from a stack of patterned two-dimensional film. From this technology arose the "systems-on-a-chip" technology, in which mechanical components (micromachines) and electrical components are combined on one chip, resulting in a single electromechanical system. Systems-on-a-chip is an excellent example of a dual-use technology that has a variety of commercial and military applications. One application is to measure the accelerations and rotations of navigation equipment. Another is in weapon safing components.

Small-Celled Polymer Encapsulating Foam

Most nonnuclear components in weapon systems (such as radars, neutron generators, firing sets, and microelectronic devices), as well as electrical components (such as computer chips) used in commercial technologies must be encased in a polymer-based material, which is a foam in some cases. This polymer encapsulant holds the components in place and prevents mechanical cracking and dielectric breakdown (a condition in which high voltage produces an electrically conducting path). Sandia scientists have discovered that when a polymer foam's cells—the small bubbles within the foam—are reduced to 0.1 to 1 micron, the foam becomes at least 10 times more resistant to dielectric breakdown than traditional, larger-celled polymer foams. This means that the new foam resists higher electric fields without forming

a conduction path. Other encapsulants having high resistance to dielectric breakdown are less mechanically forgiving than foams and are therefore more prone to mechanical cracking. An application currently being considered is use of the small-celled foam to encapsulate new firing sets.

Sandia's First 0.5-Micron Application-Specific Integrated Circuit

Sandia's first 0.5-micron complementary metal-oxide semiconductor (CMOS) application-specific integrated circuit (ASIC) has been successfully designed and fabricated in the Microelectronics Development Laboratory (MDL). Sandia needs small quantities of ASICs, but private industry is not usually interested in supplying low volumes. This Sandia-produced state-of-the-art ASIC is a major milestone in the development of the MDL as a fabrication facility for custom and radiation-hardened microelectronics. This capability is needed for nuclear weapon and space applications. The success of this device is a result of a team effort combining ASIC design and microelectronics technology.

Process Control Monitor for Agile Manufacturing

Sandia researchers have developed a process control monitor, based on a simple optical reflectance technique, that can rapidly characterize the performance of equipment used to produce compound semiconductors. Compound semiconductors are high-performance materials used for light-emitting and light-detecting devices and for very high-speed (frequency) electronics. The materials flexibility allowed by compound semiconductors is a plus in optoelectronic and high-performance devices; however, it comes at a cost of increased complexity in the manufacturing processes. Sandia's new monitor functions without interfering with the manufacturing process. It permits reliable and predictable growth of complex structures within 1 percent of design targets and in a turnaround time of days instead of months. As a result, Sandia has significantly improved its agile manufacturing capability, that is, its capability to manufacture multiple products in small numbers using very flexible and adaptable equipment, people, and processes.

Torch Chip Spin-off to Satellite Application

The self-testing integrated circuit called TORCH (Tester On a Resident Chip) has yielded a spin-off to the Enhanced Radiometer (EnRad) Satellite Program just six months after the chip was completed in the second year of a three-year internal research and development project. TORCH is an integrated circuit with specialized circuitry that assesses its own reliability (and is intended to test other ICs in the future) by looking at structures designed to identify chip failure modes. TORCH designers created both an analog-to-digital converter, capable of taking a very wide range of measurements, and an interface for setting up, controlling, and taking data. Along with low-noise amplifiers, TORCH design concepts are being implemented in a new integrated circuit that the EnRad satellite will use for rapid detection, digitization, and processing of optical signals. A number of applications are foreseeable, such as integrating TORCH-like designs into whole systems that can perform self-checks and be used, for example, to help maintain the nuclear stockpile.

A TECHNICIAN working in Sandia's Microelectronics Development Lab loads silicon wafers into a furnace designed to heat integrated circuits. Sandia uses its world-class MDL facility for much of its cooperative research with SEMATECH.

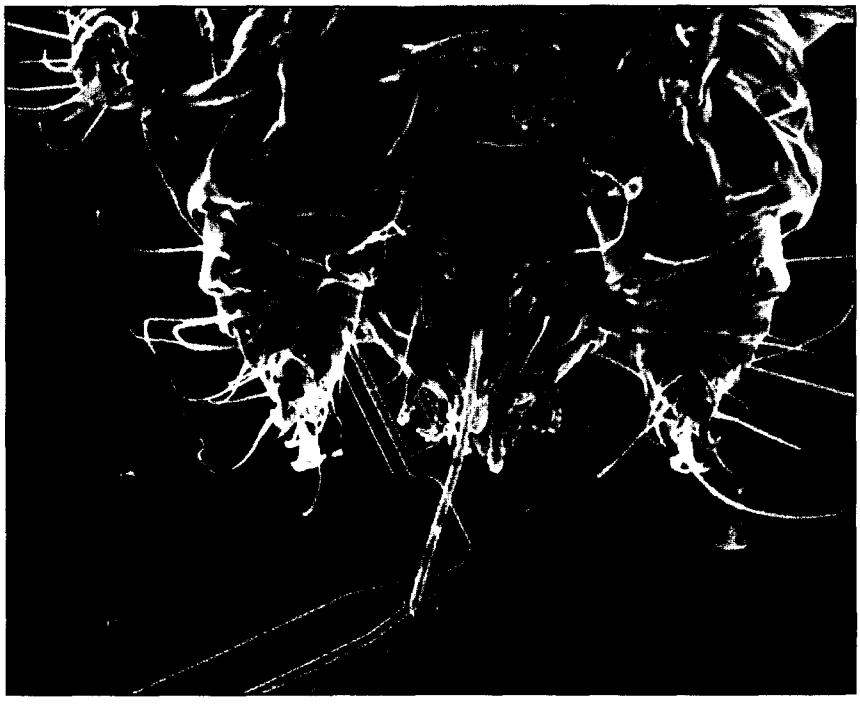
Mechanics of Granular Materials

The Mechanics of Granular Materials experiment was performed on NASA's Atlantis space shuttle during the September 1996 MIR4 mission. The purpose of the experiment was to study the mechanical behavior of sand under extremely low pressures (0.007 psig) in a nearly zero-gravity environment. Sandia provided project leadership and designed, developed, fabricated, tested, and delivered the hardware essential to the success of the experiment. This experiment provided data useful in soil mechanics, geotechnical, earthquake, offshore, mining, and many other applications.

Sematech Successes

Thirty-nine active Sandia projects, all part of a CRADA with SEMATECH (Semiconductor Manufacturing Technology, a joint industry and government consortium that addresses fundamental manufacturing problems in U.S. industry), provided technical advances for the National Technology Roadmap for Semiconductors in 1996. (A technology roadmap, the result of strategic technology planning, identifies common products and process goals, technology alternatives and milestones, and a plan for R&D activities.) More than 300 Sandia researchers contributed solutions in the areas of lithography, packaging and assembly, contamination-free manufacturing, equipment improvement, factory integration and productivity assessment, materials and bulk processing, interconnections, testing, and strategic technology. Program participants included 27 companies, three national labs, the Defense Advanced Research Projects Agency, the Department of Energy, the Air Force, SEMATECH, and SEMI (Semiconductor Equipment and Materials International, Inc.). Representatives of all these groups attended the 7th annual review last fall in Albuquerque. The 130 projects completed since the Sandia/SEMATECH relationship began in 1989 have supported Sandia's defense microelectronics mission and industry best practices.

R&D 100 AWARDS



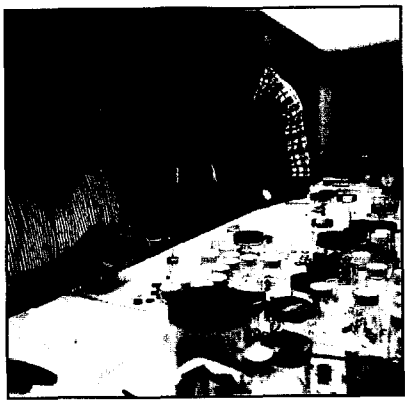
A DUST MITE crawls over a Sandia micromachine. The gear's diameter is smaller than a human hair and 1/100 the weight of the dust mite.

Integrated Mechanical and Electrical Micromachine Technology

An innovative technique for fabricating millimeter-size "intelligent" micromachines has made possible a new generation of active skid-control mechanisms for cars and other inertial measurement systems. A micromachine accelerometer is fabricated in a tiny 6-micron-deep trench on a silicon wafer and surrounded by a planarized oxide filler to recreate a flat, pristine wafer surface. The sensing circuitry, or "microbrain," is added, merging both the mechanical and electrical systems on a single thumbnail-size chip. This type of intelligent micromachine detects minute position changes to initiate corrective action on a system. These extremely tiny devices will not only shrink the size of critical weapon components—Sandia's primary goal in developing them—they will enable such innovations as vibration suppression systems that smooth rough driving, sensors that track a person's position in three-dimensional enviroments, and high-performance gyroscopes that could dramatically impact future designs of automobiles and military systems.

Low-Temperature, Low-Pressure Process to Produce Aerogels

Large-scale commercial use of aerogels—the world's lightest solids, which comprise up to 99 percent air—is now possible with a new, cheaper, and safer production technique. It replaces the conventional high-temperature, high-pressure technique, which was prohibitively expensive and hazardous. The porosity of aerogels makes them ideal insulators for heat (one inch of aerogel offers about the same thermal insulation as 10 inches of fiberglass), sound, and electricity. A thin aerogel layer on top of integrated circuits might reduce unwanted capacitance between semiconductor layers and ultimately contribute to faster, more compact computers and smaller batteries. Sandia researchers have developed a way to produce aerogels at room temperature and pressure, and for the first time it is possible to prepare aerogels using standard laboratory glassware.



Molecular design gives phosphate glass desired melting properties.

Phosphate Glass and Aluminum to Hermetically Seal Electronic Components

Manufacturers in the electronics industry can now use aluminum (instead of steel) in combination with glass to hermetically seal components. Aluminum's lighter weight and lower cost are desirable qualities, but until recently aluminum was not useful for hermetic sealing. It melts far below the temperature at which a conventional sealing glass flows evenly to form a tight seal. Sandia solved this problem by inventing a phosphate glass that melts at much lower temperatures, yet does not corrode in water. The new glass forms reliable hermetic seals and provides excellent electrical isolation between aluminum alloy shells and copper alloy pins. The new glass also has good chemical durability and a thermal expansion similar to copper's, characteristics necessary for lasting seals.

Ion Exchanger for Radioactive Waste Cleanup

By removing radioactive molecules from nuclear waste site liquids, researchers can vastly reduce the volume of radioactive material that must be handled and kept in long-term storage. Working with Texas A&M University, Sandia scientists have developed a material for removing cesium isotopes, byproducts of nuclear weapon production, from other wastes. Cesium, including the highly radioactive form that emits dangerous, penetrating gamma radiation, is a positively charged ion in solution. As a cesium-containing solution passes through an ion exchange column containing a material called a crystalline silicotitanate, or CST (which consists of a negatively charged atomic framework compensated by positively-charged sodium ions), the cesium displaces the chemically similar sodium ions from the CST, thereby decontaminating the solution. Crystalline silicotitanates are a class of inorganic oxides (which includes elements such as silicon, titanium, and oxygen) that are capable of ion exchange reactions. The amount of radioactive solution that can be decontaminated by CST depends on the composition of the solution. For example, the cesium in typical solutions from the Hanford site may be concentrated to 1/600 of its original volume, while the cesium in contaminated groundwater may be concentrated to 1/10,000 or more of its original volume. The material has been commercialized through a Cooperative Research and Development Agreement with UOP, an Illinois company. UOP currently markets both a powder and a granular form of the material suitable for column operations.

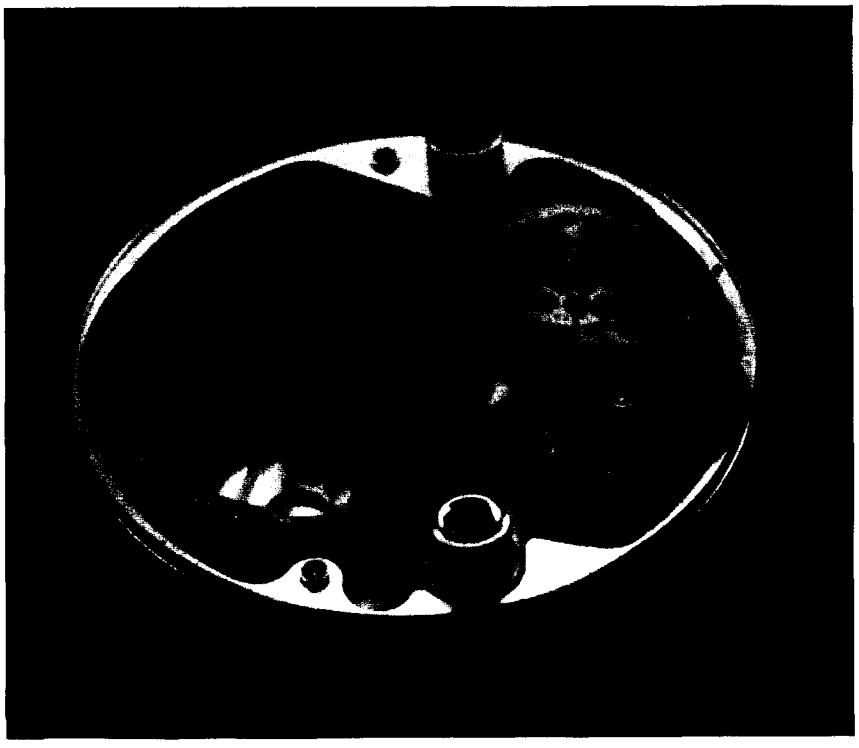
Scalable ATM Encryptor

Voice and video transmissions and any other computerized data can be kept confidential with a new device called the Scalable ATM (asynchronous transfer mode) Encryptor, which encodes data before the data is sent and decodes it upon its arrival. The scalable ATM encryptor ensures privacy and could become the basis of security for the next-generation telephone network. The device works between computers interconnected at vastly different speeds, including mainframes and personal computers. It uses standard switching and transmission technology and can be used to send information over the Internet. Messages sent using the encryptor, however, are far more difficult to tap than conventional Internet messages.

OC-12c ATM Protocol Engine

Supercomputers in different locations can work together as though they were in the same room with a new device called the OC-12c ATM Protocol Engine, dramatically improving communication between processors. The protocol engine uses the same network that the telephone industry provides for national and international communications and is not sensitive to distance. With this technology, the only thing preventing the solution of complex problems such as molecular modeling is the number of computers that can be dedicated to the task. The ATM Protocol Engine, designed by Giganet Inc. and Sandia for the Intel Paragon computer (which transmits and receives information), provides many connections through a single interface and can send millions of bits of information per second with very low delay. The connections make it possible for clusters of processors solving different parts of a problem to share problem-solving results.

NUCLEAR WEAPONS



SAFING—Miniature machining, photolithographic (LIGA) semiconductor processes, and silicon micromachining are employed to fabricate devices such as this Detonator Safing Device.

Advanced Weapon Firing Set and Stronglink Developments

New miniature firing set and stronglink subsystems have led to significant advances in enhanced nuclear detonation safety. Miniature firing sets, 100 times smaller than traditional designs, are being developed to provide nuclear safety enhancements and increased functionality in weapon system applications where volume is at a premium. These firing sets are possible with new high energy-density ceramic capacitor technology, custom optoelectronics, analog and digital application-specific integrated circuits, a poco sprytron (miniature switch tube), and advanced electronic packaging. Advances in micromechanical and electronic finite-state machine stronglinks (devices that keep

weapons safe in case of an accident), integrated with the micro firing set, enable a complete nuclear safety subsystem to fit into less than 0.25 cubic inches. Miniature and micromechanical stronglinks are enabled by lithographic-based micromachining processes. (In lithography, areas of a material are selectively treated and processed by etching, electroplating, ion implanting, etc.) LIGA is an X-ray lithography process that can produce both plastic and metal parts with tolerances 10 times smaller than are possible with conventional precision miniature machining. The surface micromachining process is based on photolithography and can produce silicon parts and assemblies smaller than the diameter of a human hair. The most compelling reason for miniaturization is to provide weapon systems with detonator safety, accomplished by placing a stronglink at a weapon detonator to ensure that the stronglink cannot be separated from the weapon system in an accident until the system is irreversibly nonfunctional. Taken together, these firing set and stronglink subsystems offer many opportunities to system designers to miniaturize and enhance the safety, security, and reliability of retrofitted weapons.

Virtual Electrical Circuitry for Weapon Telemetry Systems

A Joint Test Assembly is a weapon system whose nuclear materials have been replaced with nonnuclear representations that include instrumentation. These instrumented test weapons help ensure the quality of the U.S. nuclear weapon stockpile. A part of the instrumentation system is the telemeter, which measures various weapon environments and signals. The telemeter connects and interfaces with sensors, performs A-D conversions, handles data storage and transmission, and determines weapon functionality. Sandia researchers are now predesigning modules of virtual circuitry, which remain in a computer until needed for a new telemeter. Using modular telemetry methodology, a computer operator receives a list of customer requirements, selects the necessary predesigned modules to meet those requirements, and connects them on a circuit board of any shape for subsequent fabrication. Sandia has designed, simulated, tested, and routed an array of virtual circuit modules for weapons such as the W76, W78, W80, and W87. Since the modules exist only in a computer until needed, they do not become obsolete (as conventional, prefabricated modules do) and can be upgraded at any time. When a new telemeter is needed, front-end design work is greatly reduced because the circuitry for the individual modules has already been proven. The goal of modular telemetry is to reduce design time while increasing design robustness and flexibility.

PAMTRAK: Personnel and Material Tracking System

Sandia has developed a new Personnel and Material Tracking System, called PAMTRAK, to protect sensitive material. PAMTRAK incorporates a variety of sensors to monitor materials or workers. It integrates proximity badges (PAMTRAK can tell who is in a particular area and if they have proper authorization), weight and motion sensors, and video cameras with a computer that reports attempts to steal or divert material. It can also communicate with a site's other security systems. PAMTRAK can reduce radiation exposure to workers and save money by reducing the frequency of material inventories.

3-D Computer Simulations for Warhead Protection

The proper function of a nuclear weapon depends on the presence of neutrons during primary implosion when the plutonium is supercritical. Neutron generators

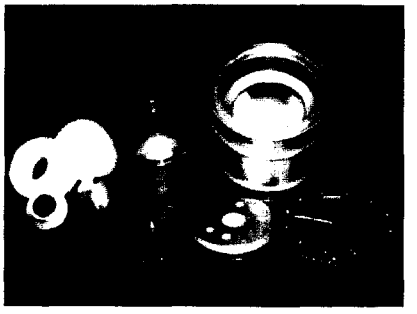
are located close to the warhead primary to produce a sufficient quantity of neutrons at that critical time. If not carefully positioned, neutron generators can be damaged by gases and materials that emerge from the primary as it is imploded by the main charge of high explosive. Neutron generators must be positioned far enough away from the primary to prevent them from being damaged until they have time to produce the necessary neutrons. Sandia has completed three-dimensional simulations and experimental correlation of this so-called "standoff phenomenon" for the Warhead Protection Program. Simulations were completed with a Sandia-developed hydrodynamic code on the Intel Paragon supercomputer. Experimental data was acquired from two primary hydrodynamic implosion tests conducted jointly with Lawrence Livermore National Laboratory. Sandia's instrumentation acquired shock histories in critical locations throughout the warhead electrical system and the neutron generators, providing data for code validation. As a result, our system designers, analysts, and shock physics experts developed an in-depth understanding of the complex 3-D explosion through which the neutron generators must survive.

Portable Integrated Video System for Post-Accident Recovery of Damaged Nuclear Weapons

In the event of a nuclear weapon accident, Sandia's Portable Integrated Video Systems (PIVS)—a fiberoptic, multichannel, multimedia communication system—would convey secure, real-time visual and verbal information from the accident site to a command post. Sandia delivered four PIVS to nuclear emergency response personnel with the Russian Ministry of Defense. The system was originally developed for the Department of Energy's Accident Response Group (a multilaboratory team) to enhance post-accident recovery of nuclear weapons. Sponsored by the Defense Special Weapons Agency, Sandia employees trained Russian military personnel to operate and deploy PIVS.

AT-400R Shipping Containers for Nuclear Waste

In keeping with the June 1992 U.S./Russian Agreement called "Safe and Secure Transportation and Storage of Nuclear Weapon Materials Through the Provision of Fissile Material Containers," the U.S. shipped 10,000 AT-400R containers to Russia during 1996. Sandia designed, developed, and tested the AT-400R containers for the Defense Special Weapons



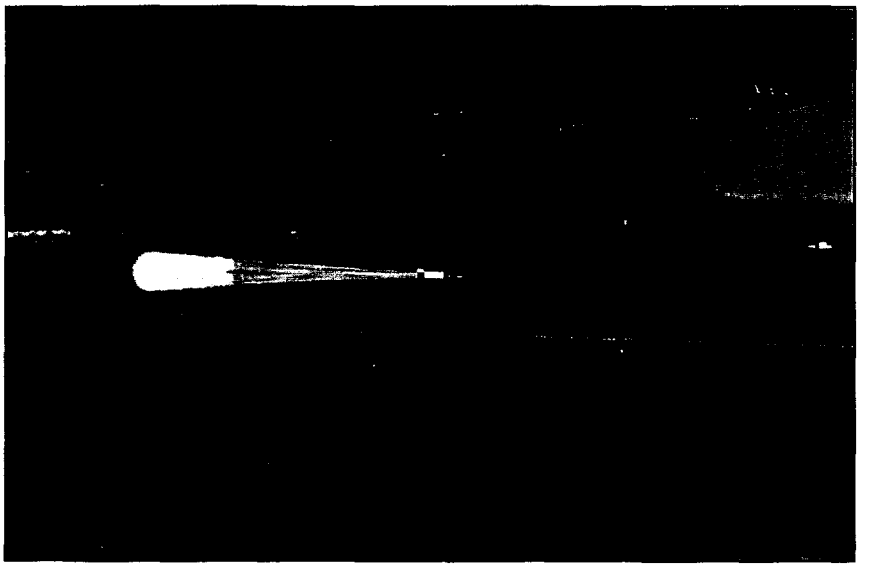
SAFE SHIPPING—Above is a model of the AT-400R shipping container designed by Sandia for transporting and storing Russian fissile materials.

Agency (DSWA). The containers, which DSWA produced and shipped to Russia, are used to transport and store radioactive material from Russia's dismantled nuclear weapons. Approximately 14,000 containers are scheduled to be shipped to Russia during 1997, and this number may be significantly increased. The AT-400A container, an outgrowth of the technology used for the AT-400R container, has been designed and will be used to store fissile materials in the U.S.

Validating Computational Models for Weapons Certification

Sandia developed new experimental capabilities to validate the capability of computational models to predict how weapons will perform in severe operational and accident environments. The Model Validation Project established a new role for Sandia's extensive laboratory test capabilities. Historically, these facilities

certified weapon safety and reliability by subjecting devices to environmental extremes such as high-velocity weapon delivery impact or accidental exposure to a jet fuel fire. New experiments and diagnostic capabilities developed for the MVP have demonstrated that Sandia test facilities can also help certify the accuracy of weapon models. Some of the most challenging experiments conducted this year involved the validation of open-air fuel-fire models, the behavior of weapon component foam encapsulants (which expand, contract, and change physical properties when burned), the extreme deformations that take place during nose crush-up events that occur as a bomb hits a target, and the transmission of high-level mechanical shock energy from the outside of the weapon into critical internal locations.



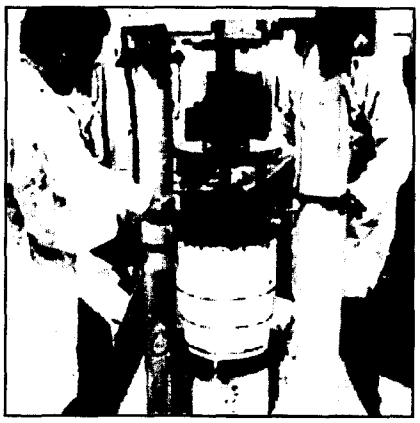
LAYING IT DOWN—A B-1B bomber on a test run deploying the B61-11 at the Tonopah Test Range. Sandia conducted 13 full-scale drop tests this year—3 in Alaska and 10 at the Tonopah facility.

Retrofit of B61-11 Earth-Penetrating Weapon

The B61-11 bomb (a mechanical field modification of the B61-7) is an earth-penetrating weapon that will replace the aging B53 bomb. The B61-11 can be delivered by a variety of aircraft including the B-2A, F16, and B-1B. The retrofit will consist of repackaging the Los Alamos-designed nuclear device and Sandia's arming, fuzing and firing electronics into a new, one-piece, earth-penetrating, steel center-case designed by Sandia. Sandia has conducted 16 full-scale drop tests this year—3 in Alaska and 10 at the Tonopah Test Range—in support of the development program. Sandia has also designed, and is fabricating for the Air Force, 10 trainers for teaching military personnel how to maintain and load the weapon before working on the real thing, along with 9 sets of handling gear (tools and equipment for routine maintenance). The B61-11 was authorized in August 1995 with a requested delivery date of December 31, 1996. Retrofit kits were delivered to the Air Force in December 1996, and retrofits began in January 1997.

Assembly Traceability Database for Weapons Assemblies

Sandia's Assembly Traceability Database (ATD) project was completed in August 1996. The ATD software captures actions such as initial builds, reworks, retirements, and retrofits on major weapons assemblies and components for weapon systems maintained within the U.S. nuclear weapons complex. In all, more than 28 million records were moved from an IBM mainframe to a Sun client-server environment. Hardware and software licensing costs are expected to be 10 times lower than previous years' costs, at an expected savings of approximately $250,000 per year.



A NEW PROCESS for dismantling the W55 warhead produced a safe, efficient, fast dismantlement.

W55 Dismantlement

Dismantlement of the W55 warhead was nearly completed in FY96. The process had been interrupted nearly three years ago because of safety concerns associated with cutting the aft case. During the hiatus, most of the dismantlement process, including the case-cutting operation and the case pin-removal process, was redesigned. These changes resulted in a safer and more efficient procedure, allowing dismantlement to proceed faster than anticipated. During FY96, all but a few of the remaining W55s were dismantled. Dismantlement was completed in early FY97.

B83 Quality Improvement Program

The third major milestone of the B83 Quality Improvement Program occurred when a B83-1, equipped with Alteration 750, was produced at Pantex and accepted by DOE in March 1996. ALT 750 incorporates into the B83-1 bomb the MC4033 dual-channel common radar system, which provides higher reliability than the previous single-channel radar system. The B83-1 also has a new and improved spin motor, a new firing set, and an encrypted permissive action link capability, which creates a more secure system by allowing operators to recode the weapon without needing to know the current code. This was the first B83 bomb to include all of these component improvements. Sandia engineers worked closely with production engineers at Pantex and AlliedSignal/ Federal Manufacturing & Technology to ensure the successful transition of ALT 750 from development to production.

Data Communication System for Nuclear Weapons

Sandia and New Mexico State University have developed a modern data communication system prototype that quadruples the frequency bandwidth efficiency of present systems. The new system can transmit data faster than 100 million bits per second. The need to retrieve more and more data from reentry vehicle experiments, flight tests, and satellites provided the motivation for developing the system. To comply with government reductions in bandwidth channel capacity, researchers applied high-efficiency data compression methods in smaller and smaller channels. Advances in digital signal-processing and digital encoding techniques for error correction made the improvement feasible. The system has the potential to achieve another four-fold improvement in both the bandwidth efficiency and data communication rate in the near future.

Prototype Vehicle for Transporting Nuclear Weapons and Materials

Sandia has completed a prototype vehicle for transporting nuclear materials and weapons on time and within budget. The prototype vehicle, a specially designed trailer, has provided an opportunity for the customer, DOE's Transportation Safeguards Division, to assess the product prior to production. A successful Nuclear Explosive Safety Study was conducted in June 1996 to ensure that nuclear safety issues were adequately addressed in the vehicle design. The Final Design Review was completed in July 1996. Production has been authorized and the first transport vehicle is scheduled for delivery in December 1997.

Nuclear Weapon Detonator Models

Sandia has developed electrical models of all the detonators used in the nuclear weapons enduring stockpile. These models simulate and characterize the electrical properties of detonators when the weapon firing system sends them a signal to initiate detonation. The models also characterize the detonators' behavior immediately after their burst, which has not been achieved before. These electrical models have been validated with high-fidelity data collected during testing in the Explosive Components Facility. The models provide a critical stockpile stewardship foundation for analyzing firing system design margins and trouble-shooting future anomalies. Models also allow different subsystem designs to be explored on the computer before the subsystems are built and tested in the lab, reducing development time and cost.

Military Liaison's Nuclear Weapons Training

Sandia's Military Liaison provides stockpile support through classroom and field training in weapon handling and maintenance, explosive ordnance disposal, bomber/fighter crew procedures, and weapon refresher training to DoD and DOE personnel. In FY96, Sandia trained more than 1,500 students—a 50-percent increase over recent years—because of the growing demand for nuclear weapon skills, knowledge, and qualification. At the three-day *Symposium on Nuclear Weapons,* more than 200 Sandians reviewed the nuclear weapons program, received feedback from customers, and discussed future challenges.

CLASS ACT— Shown here are some of the 1,500 students who participated in training coordinated by Military Liaison during 1996.

Guideline for NWC Processes for Handling Software Product

Members of the Software Quality Assurance Subcommittee of the Nuclear Weapons Complex (NWC) Quality Managers produced a document titled "Guideline for NWC Processes for Handling Software Product." These guidelines are intended to help NWC personnel develop, qualify, deliver, receive, or accept weapon-related software products for end-use customers. These guidelines support the requirements of the Product Realization Process, supplement existing engineering procedures, and are consistent with DOE procedures and requirements. Four software processes are included:

Identification: Defining what elements constitute the product and how those elements will be labeled by the supplier.

Qualification: Ensuring that the product and all associated processes are capable of meeting customer requirements.

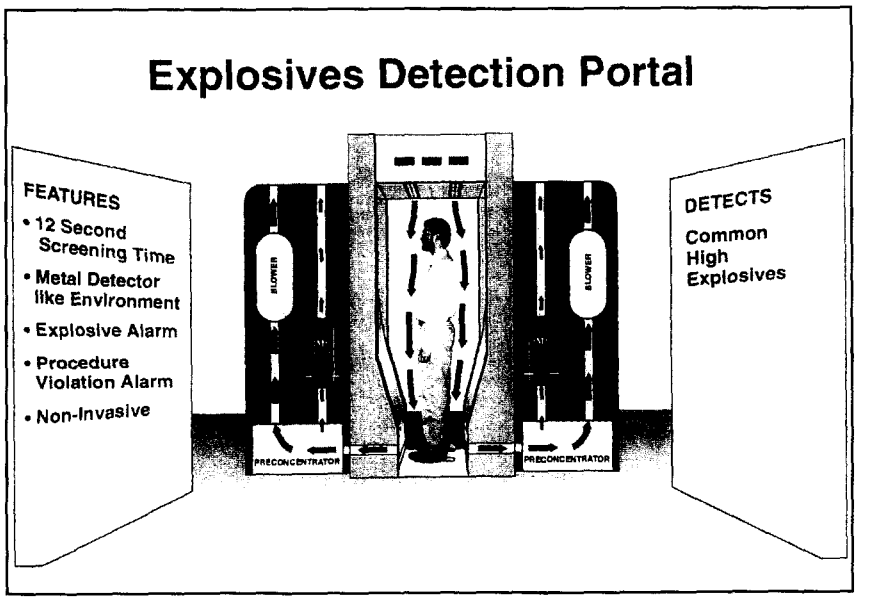
Acceptance: Ensuring that product quality activities have been accomplished.

Delivery: Enabling a product to be transferred with appropriate control from its supplier to its customer after completion of product engineering and qualification.

ARMS CONTROL

Nuclear Weapon Evaluation

Ten or eleven weapons selected from each type of nuclear weapon are tested annually to continuously demonstrate the reliability, safety, security, and readiness of the nation's nuclear stockpile. In FY96, Sandia's Stockpile Surveillance Program evaluated 113 nuclear weapons in test configurations at Sandia's Weapons Evaluation Test Laboratory at Pantex. Nuclear material is removed from the weapons and replaced with instrumentation packages that make the weapon look, act, and fly like a real warhead. Seventy-four weapons were tested in various environmental conditions, and thirty-nine warheads were flight tested with operational delivery systems. Some weapons are tested in the laboratory by removing their fissionable material, reassembling them in a "go-to-war" configuration, and attaching them to a tester. The advantage of simulated testing is that tests can be repeated in various environments and all weapon parts can be recovered. Twenty significant finding investigations were conducted to determine the reliability, safety, and appropriate corrective actions for anomalies detected during the tests. Sandia reported all results to the Department of Energy's Weapons Quality Division.



Explosives Detection Portal for Airports

Sandia designed a walk-through explosives detection portal for the Federal Aviation Administration (FAA) to screen passengers for common explosives. The preconcentrator technology is what makes this portal possible. The preconcentrator is a device that collects minute vapor and particulates from the large volume of air surrounding a person standing in the portal. The preconcentrator then transports the collected vapor and particulates to an ion mobility spectrometer that can detect explosives in concentrations as low as four parts per trillion. Breakthroughs in this technology have resulted in a preconcentrator that is 1,000 times more sensitive, 200 times smaller, 13 times less expensive, and 4 times faster than previous preconcentrator models. Consequently, the portal will exceed the FAA's explosives detection goals. A working prototype of the portal for field testing is scheduled for delivery in June 1997. The preconcentrator technology can be adapted to detect environmental hazards, chemical or biological agents, narcotics, and land mines.

Ground Nuclear Detonation Detection System Terminals

Ground Nuclear Detonation Detection System Terminals receive simultaneous sensor data from up to 24 Global Positioning System satellites on the lookout for nuclear bursts. The terminals process the data to produce a real-time nuclear event report in support of nuclear attack assessment and force management. Sandia developed the software; procured the rugged antenna, receiver, and computer equipment; and integrated the terminal into the user's mobile command and control system. The ground terminals were delivered to U.S. Space Command and U.S. Strategic Command.

Ultraviolet Laser Remote Sensing for Analyzing Unknown Materials

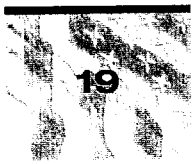
Sandia is developing new capabilities in ultraviolet laser remote sensing as part of a Department of Energy-sponsored multilaboratory program. In this technology, ultraviolet laser light is propagated through the atmosphere to interact with gaseous, liquid, or solid effluents. The target materials absorb UV energy and commonly emit visible light (fluorescence). To determine the chemical components of an unknown material, researchers measure the amount of UV energy that the material absorbs and the emitted fluorescence. Because each chemical has unique absorption and fluorescence properties, the measurements are a fingerprint of the unknown material. Activities in 1996 culminated in highly successful field tests at the Nevada Test Site, where researchers demonstrated an integrated multispectral fluorescence and absorption-based lidar (light detection and ranging) from significant distances and against blind targets controlled by DOE. Although the prime application of this work is the detection of nuclear weapon proliferation, plans are under way to apply this technology to the growing threat of terrorist and military use of biological weapons. The technology may also be applied to environmental issues such as analyzing a facility's exhaust or discharged materials, and has the potential for additional spin-offs.

Portable Gate Monitoring System

Sandia's Cooperative Monitoring Center (CMC) has designed and deployed a nonintrusive portable gate monitoring system, equipped with sensors and video equipment to detect the presence, length, direction, and weight of vehicles leaving a facility. The system was designed to monitor movement of treaty-limited items such as missiles and artillery equipment. Attempts to bypass the system or tamper with sensors can also be detected. The monitoring system was demonstrated to foreign journalists from the Middle East and South Asia. The same system was redeployed at another Sandia facility and demonstrated remotely from Canada during the North Pacific Arms Control Workshop, which hosted representatives from the U.S., Canada, China, Japan, Russia, and South Korea. Additionally, the CMC has developed a portable display of monitoring technologies for use at international forums. The passive and active displays of cooperative monitoring concepts can be reconfigured to complement various conference themes.

Tactical Unattended Ground Sensors Program

The Tactical Unattended Ground Sensors Program is responsible for developing a sensor system to aid in counterproliferation efforts. During 1996, a proof-of-concept experiment at the Nevada Test Site, funded by the Defense Special Weapons Agency, demonstrated the ability to remotely detect, identify, and locate industrial machinery. This is a multiorganizational program that includes participation by Sandia and Lawrence Livermore national laboratories and ENSCO Inc.



Physical Protection of Nuclear Material

The proliferation of nuclear weapons is a major threat to international security and stability. Sandia provided technology and expertise in upgrading the physical protection of nuclear material in selected facilities in the Former Soviet Union. Activities included installing security systems that detect intruders, monitoring the movement of nuclear material, and providing physical improvements to facilities that store and use nuclear materials. The project involved physical protection systems analysis, design, implementation, and testing. Despite cultural differences, Sandia and the Former Soviet Union benefited from the exchange of physical protection philosophies and international project management experience. Work continues on upgrades at 44 Former Soviet Union facilities.

Cooperative Monitoring Center Workshops

Sandia's Cooperative Monitoring Center (CMC) promotes communication among political and technical experts from around the world and is a resource for the U.S. government and the international arms-control-and-monitoring community. The CMC conducted training workshops at Sandia during 1996 on cooperative monitoring technologies for representatives from China, South Asia, the Middle East, South Korea, Northeast Asia, Russia, and Latin America, including a verification training course for the Israeli delegation to the Middle East Arms Control and Regional Security Process, sponsored by the Arms Control and Disarmament Agency. These workshops for political and technical experts promote development of the expertise needed to negotiate, evaluate, and implement regional arms control and confidence-building agreements.

CMC Workshop

Multispectral Thermal Imager Satellite

A memorandum of agreement for the launch of the Multispectral Thermal Imager satellite was signed in early January 1997 by the Air Force Space Test Program Office and the Department of Energy. This is a research and development project, sponsored by DOE and implemented by a Sandia-led team that includes Los Alamos National Laboratory, Savannah River Technology Center, the Air Force Phillips Laboratory, and several industry contractors and universities. The project objective is to develop, demonstrate, and evaluate an advanced satellite-based sensor system for national security and civilian applications.

The agreement is the result of high marks from the Air Force and Department of Defense Space Experiments Boards, based on military relevance and experiment quality. The satellite will simultaneously image cooperative, instrumented sites in 15 spectral bands, ranging from visible to long-wave infrared. Satellite data will be compared with ground truth to evaluate system performance and utility.

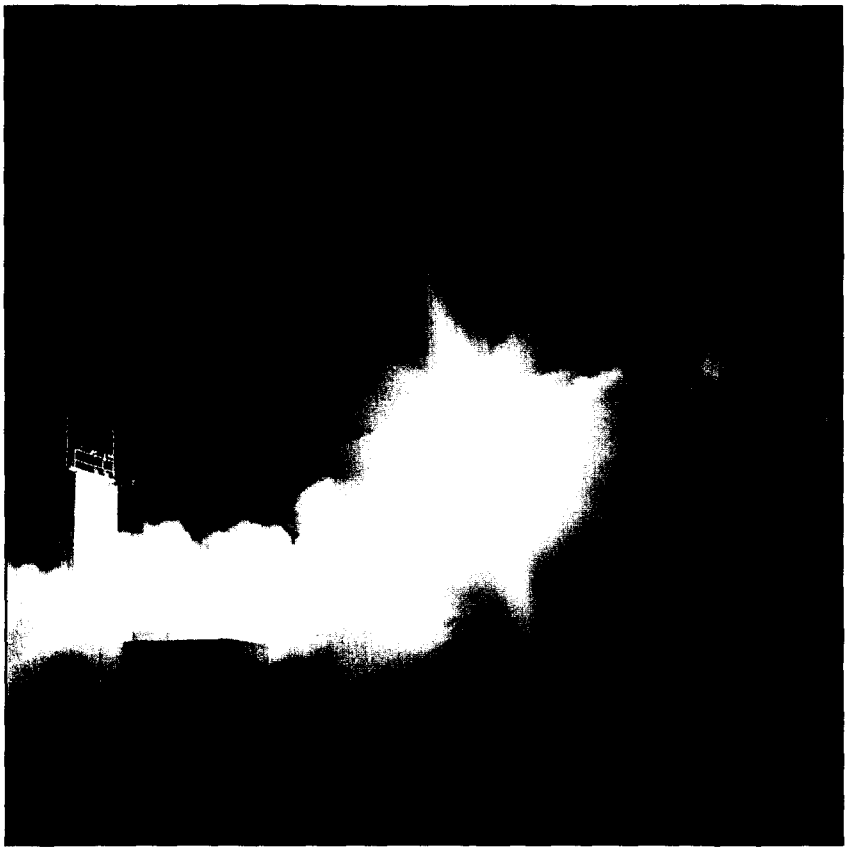
Computer Code for Estimating Seismic Network Performance

Sandia modified a large network simulation code called NetSim, which predicts how well a network of seismic listening stations can monitor earthquakes and nuclear blasts anywhere in the world. This code uses measured or assumed station characteristics (such as the background noise level and the accuracy by which a wave arrival time can be measured) and propagational models (for example, how a given wave type at a given source intensity decays with distance and how much time the wave takes to propagate that distance) to estimate a network's capability to detect and locate seismic events. Typical performance measures include the probability that the network will detect an event of a certain size and location, the event size that can be detected at a specified location with a required confidence level, and the accuracy with which an event can be located. The enhancements to the code included an improved statistical basis for estimating the accuracy in locating an event, a more complete detection model, an expanded supporting database, and additional station capacity (256 seismic listening stations). A user-friendly graphics interface (NetCon) displays the performance estimates. The revised NetSim has been applied to a variety of scenarios for the benefit of the U.S. delegation that helped negotiate the Comprehensive Test Ban Treaty (CTBT) at Geneva. More recently, the code provided Department of Energy researchers with insight as to how their efforts in calibrating regions and stations can improve the capability of the planned CTBT network to locate nuclear blasts. Sandia's NetSim predictions have been made available to various DOE researchers, government contractors, and the National Academy of Sciences to support U.S. interests in monitoring research.

Waveform Correlation Event Detection System

To help monitor the upcoming Comprehensive Test Ban Treaty, Sandia has developed a new algorithm for detecting natural events and man-made events (such as nuclear tests) as they occur all over the world. The Waveform Correlation Event Detection System can identify events with a worldwide network of sensors that collect data 20 to 40 times each second. An event is recognized if the incoming waveforms closely correlate to a pattern that would be expected to occur in an event. This technique overcomes an exponential increase in computing time experienced by previous algorithms when trying to deal with the large quantity of data and low signal-to-noise ratios needed to monitor the treaty. The system has produced encouraging initial results and may be operational by the year 2000 at the U.S. National Data Center in Florida.

NONNUCLEAR WEAPONS



LAUNCH OF STARS II booster rocket system.

Midcourse Space Experiment Satellite Sensor Test

Sandia launched a STARS II booster rocket system from the Kauai Test Facility on Aug. 31, 1996, to support the Midcourse Space Experiment (MSX) satellite. The primary purpose of this mission was to provide target objects to evaluate and calibrate the MSX sensors. Twenty-four target objects were deployed from the Sandia-designed Operational Deployment Experimental Simulator post-boost vehicle (a part of the STARS II rocket system), which maneuvers in space under its own guidance system. The satellite was tested to see if it could track the targets and discriminate between them. Sandia designed and developed all but two of the target objects and coordinated all payload and missile integration efforts. The mission was highly successful, and significant target signature data was collected for the National Missile Defense Programs. The Ballistic Missile Defense Organization sponsors this program, which is coordinated through the U.S. Army Space and Strategic Defense Command.

Low-Cost GPS Guidance for Tactical Munitions

Several U.S. Global Positioning System (GPS) satellites are always visible, and each one transmits encrypted information (using the military Y-code) that is unique to that particular satellite at a specific location. GPS receivers use those signals to determine position and velocity. Low-cost missiles, bombs, and artillery projectiles, using guidance algorithms in the weapons, can receive the signals and use them to guide weapons to targets. The Low-Cost GPS Guidance for Tactical Munitions Project has developed a low-cost technology that enables a munitions GPS receiver to acquire navigation solutions from the Y-code satellite signals in exceptionally short time. Fast acquisition to the encrypted Y-code (possibly the only signal

that would be available under conflict conditions) is vital because of short flight duration. Sandia accomplished an acquisition time of six seconds, five times faster than the previous record. Once the weapon acquires a GPS solution, it continues to compute updates of its position and velocity every second. The Low-Cost GPS Guidance for Tactical Munitions Project, funded through the Joint DoD/DOE Memorandum of Understanding for Non-Nuclear Munitions Technology Development, has also provided a low-cost GPS antenna that has a greater sensitivity to the satellites above than to ground-based jammers located below the weapon. This antenna can be mounted onto inexpensive spinning missiles or projectiles to reduce the weapons' vulnerability to jamming signals.

ADVANCED MANUFACTURING

COMPUTER programs allow paperless design of complex parts such as weapon components. The software-based process significantly reduces fabrication time and cost.

Flight Test Program

For the first time at Sandia, a complex part was taken from concept to flight-quality part with a completely paperless process. The polycarbonate nose tip of the Bomb Impact Optimization System Flight Test Program is a complex shape requiring five-axis machining capability. The project required no drawings. Using Pro/Engineer computer-aided design software, researchers developed solid models of the part that were compatible with the software packages used for finite-element analysis, numerically controlled machining, and computer-aided inspection. The

new process allows changes to be made without significant downtime, even as the part is being machined. Inspectors use a subset of Pro/Engineer software to verify that the dimensions of the finished part fall within the specified tolerances of the design.

Intelligent Systems for Induction-Hardening Processes

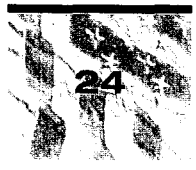
A Sandia team won the Lockheed Martin NOVA Award for "developing an intelligent controller for induction hardening, the first technology developed under the Partnership for a New Generation of Vehicles and deployed in production." Induction hardening is a widely used manufacturing process that enhances the strength, wear resistance, and toughness of components made from medium- and high-carbon steels (defense applications include advanced penetrators). Under a CRADA with GM, Sandia developed hardware and software systems into real-time process monitors and controllers, which are presently controlling the case depth of intermediate shafts in Saturn automobiles with a precision five times better than industry standards. A computational model is now being developed that couples electromagnetic, thermal, mechanical, and materials information to predict component performance and to determine a heating profile, a hardness profile, and information on the product's microstructural evolution and residual stress distributions. The new system for monitoring and controlling the induction-hardening process can optimize components while improving their reliability and reducing their weight by up to 30 percent. President Clinton has praised this project as a labs-industry success story.

Archimedes Computer-Aided Assembly Planning System

The Archimedes computer-aided assembly planning system can accept the output of most major computer-aided design systems and use it to prepare an assembly sequence plan. Specifically, Archimedes decides the order in which parts should be removed or assembled (and generates directions for this procedure), whether certain tools can fit into the assembly, and whether a particular design is geometrically valid. It can write a detailed script of the resulting plan to assist in automatic programming for robot assembly. Archimedes can be used to generate images for manufacturing documents or to immediately output a draft video for collaboration or sales presentations. It can output files to interface with sophisticated movie software, substantially reducing the effort required to produce high-quality assembly videos. Archimedes was successfully applied to a 303-part subassembly of the center-case of a B61, and the output was used to create a WaveFront animation of the resulting assembly sequence. The system was also able to successfully plan and animate a 474-part missile subsystem for an external customer, although its current practical range for routine applications is about half that number of parts. Archimedes is perhaps most useful for weapon assemblies such as missiles or other complex, compact objects.

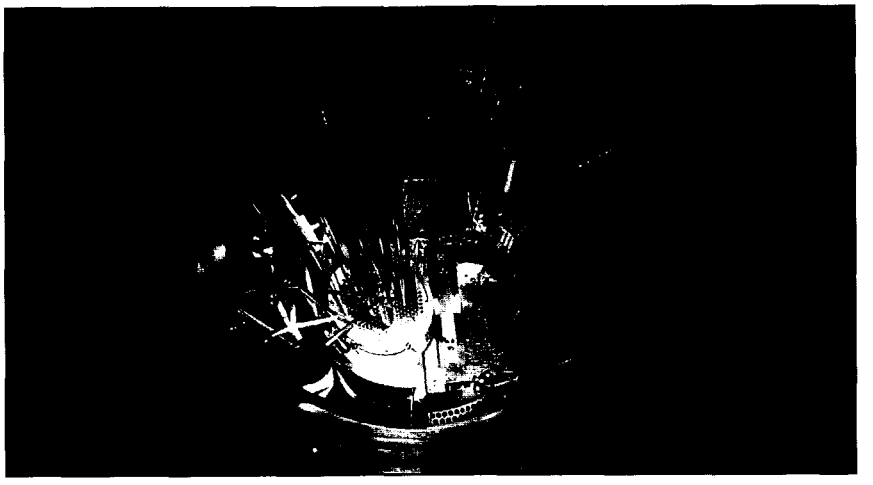
Electronic Traveler for Tracking Manufacturing Processes

The Electronic Traveler, a Sandia-developed software program, tracks the progress of components and subassemblies as they go through the manufacturing process. The prototype Traveler incorporates a Web-based interface that enables design engineers, process engineers, machinists, and inspectors to have direct access to their individual section of the design database to easily enter product information. Historically, a paper record was initialed by each contributor and traveled with the part as it advanced through the manufacturing process. The Electronic Traveler replaces the paper system and has the added advantages of providing rigorous



access control and serving as an electronic archive of manufacturing, test, and inspection information. Data integrity is maintained by password control and by storing the data in the corporate Product Data Manager system. Using the Sandia standard Web browser, the Electronic Traveler allows engineers, machinists, and inspectors to directly view a ProEngineer solid model using Virtual Reality Modeling Language and to access a ProEngineer drawing using Adobe Acrobat.

ENERGY AND ENVIRONMENT



MOLY-99—Inside Sandia's Annular Core Research Reactor, which has been selected by DOE to produce medical isotopes for the U.S. medical industry.

MOLY-99 Production at Sandia

Sandia produced its first samples of the key medical isotope molybdenum 99 (moly-99), achieving a major milestone in the Department of Energy's Moly-99 radioisotope production program. In September 1996, DOE selected Sandia's Annular Core Research Reactor (ACRR) and Hot Cell Facility as the site to produce this widely used medical isotope. Currently, the U.S. is supplied exclusively by a single reactor in Canada. Soon, though, Sandia, will become the sole U.S. producer of this isotope. Sandia is scheduled to supply moly-99 for Food and Drug Administration testing in late 1997 and to start supplying pharmaceutical houses by mid-1998. Moly-99 is currently used in 10 million nuclear medical procedures per year in the U.S. The ACRR may also be called upon to produce other medical radioisotopes such as iodine 125, iodine 131, and xenon 133.

Nuclear Reactor Pressure Vessel Tests

Sandia researchers are performing large-scale tests and related analyses to understand the failure of commercial nuclear reactor pressure vessels under the thermal and pressure loads associated with a

severe reactor accident. The reactor pressure vessel contains the reactor core, which consists of fuel assemblies and associated support structures, as well as the water (coolant) that passes over the fuel assemblies to harvest the heat generated by nuclear fission. An unplanned loss of coolant can lead to a core meltdown accident. In such an accident, the molten reactor core—with temperatures as high as 3,000°K—can collect in the lower part of the reactor pressure vessel and if nothing is done to intervene, radioactive material could melt through the vessel. Sandians are developing material behavior models to characterize how vessels will deform before rupturing. These models will then be used in computer programs to predict how pressure vessels will perform under stress. New models are needed to replace previous models, which incorrectly predicted that the Three Mile Island Unit 2 vessel would fail (which it did not—the fuel rods failed) when subjected to dangerous thermal and pressure loads, indicating that pressure vessels are stronger than previously believed. In 1996, three of eight planned tests were conducted on vessels one-fifth the size of actual vessels. These tests are designed to investigate the effect of nonuniform heating on the rupture failure of reactor vessels and have generated strong international interest.

Borehole Technology: Surface Area Modulation Telemetry

A communication technology called Surface Area Modulation telemetry offers a possible breakthrough in petroleum field operations and has attracted considerable interest from the petroleum industry. A power supply at the surface of a borehole connects to oilfield equipment such as drill pipes, rods, and tubing. This equipment supplies the tie between the power supply and a downhole package of sensors located inside the borehole. This novel link is two orders of magnitude faster than current technologies and transmits real-time downhole data from the sensors to the surface for production monitoring and formation evaluation. In the past, the borehole was either observed from the surface or operations were stopped and equipment removed so that a testing wire could be sent down, which meant data was not collected while the operation was under way. Alternatively, test data were recorded during the process but had to be retrieved later, preventing real-time control. Surface Area Modulation telemetry offers real-time data, a vast improvement over previous methods to gather borehole data. A commercialization effort has attracted nine companies, and a cooperative agreement to jointly develop commercial products is being negotiated.

Risk Assessment for NASA Space Missions to Outer Planets

Computers and other instrumentation for NASA space missions to the outer planets cannot use batteries or solar power sources because of the length of the journey—about seven years—and the distance from the sun. Electricity is instead provided by radioisotope thermoelectric generators fueled by plutonium-238, which provides electricity through conversion devices as it decays. Since such spacecraft are often launched using a gravity-assist maneuver, they may pass by the Earth so that our planet's gravitational field can "slingshot" them into deep space. The Interagency Nuclear Safety Review Panel requires a detailed risk assessment that analyzes the probability of a radiation release during launch and re-entry accidents. Sandia, at the request of Lockheed Martin Missiles and Space Systems, developed a mathematical technique to analyze comprehensive accident scenarios, including a detailed thermochemical kinetics model of a theoretically possible launch accident involving a rocket fuel fireball and the plutonium transformations within it.

YUCCA MOUNTAIN— A Sandian puts final touches on the insulation covering the Single Heater Test Block. More than 600 data channels of instrumentation were inserted into 34 boreholes to measure temperature, moisture, and displacement in the rock mass.

Analysis of Thermal Processes at Yucca Mountain

One of the major remaining issues in the characterization of Yucca Mountain as a potential high-level nuclear waste repository is an understanding of the thermal processes that will occur when nuclear waste is placed in the facility. The heat emitted from nuclear waste as it decays will interact with the surrounding rock, causing water in the rock near the waste emplacement areas to turn to steam. As the steam moves through fractures to cooler areas, it will condense and possibly flow down through rock fractures into the nuclear waste area. A detailed understanding of how this process may affect changes in temperature and humidity near the waste packages is essential to predicting the corrosion rate and ultimate lifetime of waste packages. Tests at the underground Exploratory Studies Facility (ESF) at Yucca Mountain were designed to better understand these thermal processes so that a model could be developed for predicting the waste package environment over the lifetime of the repository. Sandia was a major participant in the design and fielding of the first ESF thermal tests, which involved a single heater emplaced in the rock mass. Instrumentation around the heater measures essential data such as temperature and humidity. A larger full-scale test that will simulate a repository emplacement room has been designed and is scheduled to start in December 1997. This test will study hydrothermal and thermomechanical processes at the site on a scale representative of repository storage rooms.

Development of Fuel Cells

Sandia led the development of the Russian/American Fuel Cell Consortium (RAFCO), under the auspices of the Gore-Chernomyrdin Commission. Former Secretary of Energy Hazel O'Leary and Russian Minister of Atomic Energy Viktor Mikhailov met in Vienna, Austria on September 16, 1996, and signed an international agreement to implement RAFCO. The consortium will help focus the expertise of both countries on accelerating the development of fuel cells for emerging markets while promoting nonproliferation goals. Fuel cells are an electrochemical power source analogous to a battery. Low-temperature fuel cells can run on pure hydrogen or on natural gas that is converted into hydrogen and carbon dioxide. The carbon dioxide is discarded, while the hydrogen dissociates at the negative electrode to form hydrogen ions. Electrons are released into the external circuit, and the hydrogen ions migrate across the fuel cell to the positive electrode, where they merge with oxygen ions to form water and produce electricity. Fuel cells are an environmentally

friendly energy source that can be used to power homes and heat buildings. They could also be used to power automobiles—one option being considered for the Partnership for a New Generation of Vehicles initiative to produce an 80-mile-per-gallon car is to replace the internal combustion engine with the more efficient fuel cell. RAFCO projects will team Russian nuclear institutes, DOE national laboratories, and U.S. and Russian industry.

Soybean Hydraulic Fluid

In an effort to increase the use of biodegradable lubricants by U.S. industry, Sandia is testing soybean hydraulic fluid in selected pieces of road equipment from several manufacturers. Researchers are using the U.S.-grown, pollution-reducing oil in forklifts, graders, sweepers, and garbage trucks in a joint field test with the University of Northern Iowa. After the field test period and subsequent approval of the product, Sandia plans to use the soybean product in all of its hydraulic equipment. Soybean lubricants, developed by an associate professor at UNI, are expected to perform as well as other hydraulic oils, and the vegetable-based fluid should be easier to discard once proper government regulations are in place.

Observation of Combustion in Diesel Engines

The details of the early stages of diesel combustion, from fuel-air mixture preparation through autoignition and the onset of soot formation, are being unveiled using a special research diesel engine and advanced laser-sheet imaging diagnostics. This research engine is derived from a production diesel engine fitted with quartz windows that allow optical access into the combustion chamber. A sheet of laser light (approximately 25 mm wide by 0.3 mm thick) projected into the engine through a window at the top of the cylinder wall slices through one of the burning fuel jets and creates an optical signal. This optical signal is imaged via mirrors through windows at the top and bottom of the combustion chamber using a special video camera. Various laser-light wavelengths and optical filters enable imaging of fuel droplets, soot particles, or various types of gas-phase molecules. The goal of this research is to gain a fundamental understanding of diesel combustion to help manufacturers design engines that meet new emissions and efficiency requirements. This work, part of a Cooperative Research and Development Agreement, received the Society of Automotive Engineers Horning Memorial Award.

Record 26-Hour Atmospheric Research Flight

Uncertainty about how the sun interacts with clouds is one reason for differences between General Circulation Models (GCM), used for predicting global climates. To observe atmospheric heating and cooling cycles—vital information for GCMs—a Sandia-led multilaboratory team, working for the Atmospheric Radiation Measurement-Unmanned Aerospace Vehicle (ARM-UAV) program, sent a high-altitude Unmanned Aerospace Vehicle into the atmosphere above the Cloud Radiation Test Bed Facility in Oklahoma, where it recorded data on heating and cooling for a record 26 hours. One UAV with a consistent set of instruments was used for this study to avoid calibration or instrumentation questions that arise when two or more planes are used to collect data over a long-term (complete day-night) testing cycle. The data provided by the ARM-UAV program, supported by the DOE and DoD Strategic Environmental Research and Development Program, will help improve large-scale meteorological and climate computer models and improve satellite calibration.

Tritium Research Lab Conversion to Chemical and Radiation Detection Lab

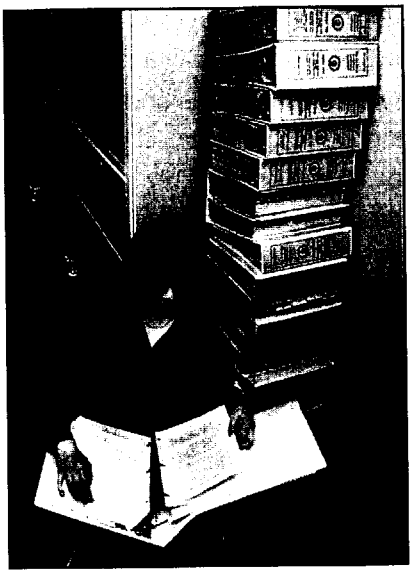
A major accomplishment at Sandia/California in 1996 was the successful cleanup of the former Tritium Research Laboratory (TRL) and its subsequent conversion to the new Chemical and Radiation Detection Laboratory (CRDL). The TRL had operated for 17 years as a state-of-the-art facility for conducting advanced research and development studies with tritium, a radioactive isotope of hydrogen. All of the TRL's equipment had to be decontaminated and decommissioned, resulting in a modern, high-quality facility, the CRDL laboratory. This new facility has been dedicated to the support of Sandia's rapidly growing Advanced Detection Technologies Program. CRDL is the centerpiece for Sandia's growing business in sensor development.

Research Project: The Origin and Fate of Burned Hydrocarbons

Sandia successfully completed a three-year, $7 million research project to understand how air toxic species (byproducts created when hydrocarbon fuels are burned) originate and what ultimately happens to them in industrial processes. Inhaled byproducts of burned hydrocarbon fuels can be harmful or even carcinogenic. Natural gas was the hydrocarbon fuel studied most. The project involved seven CRADA partners (five refineries and two natural gas producers), two universities, and two national laboratories. The study revealed that most byproducts are destroyed when burned under normal conditions, but if the process deviates significantly from normal conditions, the toxic substances could escape and be a cause for concern. Industry will use the data to minimize the generation of undesirable toxic species. The Petroleum Environmental Research Forum partners will also use the data for discussions with the Environmental Protection Agency. These discussions will significantly influence the next generation of regulations governing the performance of industrial process heaters.

Application to Open Waste Isolation Pilot Plant

The last significant step toward opening the Waste Isolation Pilot Plant (WIPP) was to submit the Compliance Certification Application (CCA), which was completed and submitted 62 days ahead of schedule to the Environmental Protection Agency for review. A successful review of the CCA would mean that in November 1997, WIPP could begin receiving transuranic waste—waste contaminated by plutonium and other man-made elements that are heavier than uranium. Included as part of the application were contaminant transport models, based on Sandia-developed field tracer tests. These tests predict the speed at which contaminated water would travel through an important fractured rock layer that overlies the WIPP repository, in the event of a human-induced breach of the repository.



SANDIA'S WIPP Deputy Project Manager scans the first volume of 20,000 pages of documentation presented to support DOE's Compliance Certification Application to EPA.

Environmental Restoration Document of Understanding

A document of understanding that summarizes all agreements relating to the acceleration of the Sandia and Los Alamos environmental restoration projects was completed in April 1996. The

document ensures consistency across both environmental restoration projects and regulatory agencies in accomplishing corrective actions. The document describes the technical approaches that Los Alamos and Sandia National Laboratories will take to address such issues as voluntary corrective action for site cleanup, land use, environmental sampling, regulatory permit modification, groundwater monitoring, and cleanup levels. The project was a joint effort of the Department of Energy, Los Alamos, Sandia, the New Mexico Environment Department, and the Environmental Protection Agency. The team won a 1996 gold DOE Team Quality Award.

New Approach to Air Quality Permits

Sandia was the first Department of Energy site to have its application for an air quality operating permit deemed complete, which resulted in Sandia being nominated to participate in the Environmental Protection Agency's (EPA) Regional Pollution Prevention in Permitting Pilot project. As part of the ongoing project, Sandia is adopting an innovative approach to the U.S. Congress' Clean Air Act by working with City of Albuquerque and EPA regulators to develop a facilitywide operating permit that does not increase recordkeeping or reporting burdens, but will save money and allow flexibility. Permit language will ensure future flexibility, an important incentive for companies considering working with Sandia. Currently, a new project could take up to 18 months to be approved. But framers are drafting a permit that will incorporate preapprovals for a variety of scenarios so that new projects can begin without waiting for permit modifications. This project may become a benchmark for drafting air quality operating permits at other research and development facilities.

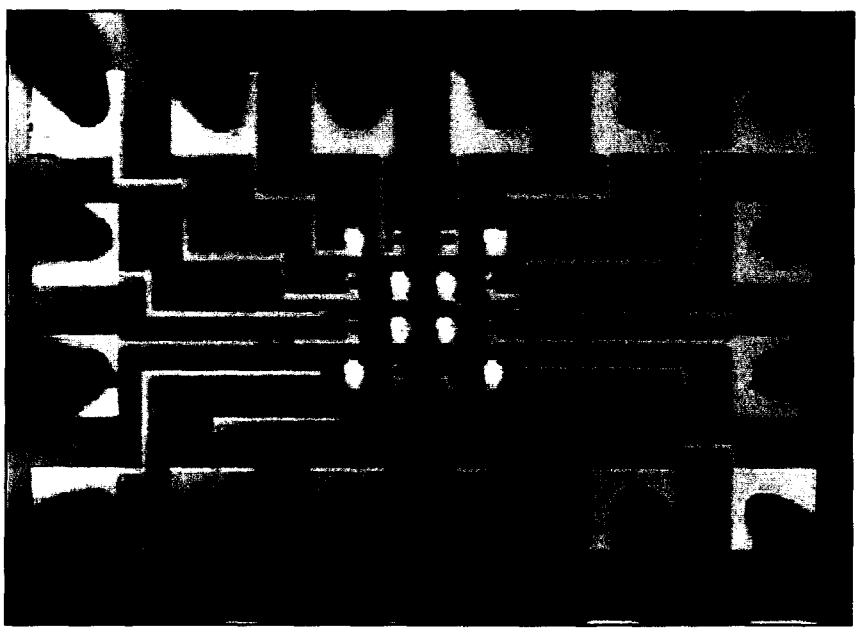
Environment, Safety and Health Hazards Assessment Software

Software has been developed at Sandia to provide a consistent and standard process for addressing hazards and environmental issues across the laboratories. The software, called Integrated Safety, Environmental, and Emergency Management System, consists of four modules: the Primary Hazard Screen, the Environmental Checklist/Action Description Memorandum, the Hazards Analysis, and the Building Profile. The software helps managers determine the facility or project hazard classification, required safety documentation, and required training based on current regulations and Department of Energy orders. The Primary Hazard Screen and Hazards Analysis modules take only two to four hours to complete and replace the Preliminary Hazards Analysis form, which could take weeks of preparation time. In pilot testing, the system was enthusiastically acclaimed by a sampling of Sandia organizations.

Sandia Support for Pantex Site-Wide Environmental Impact Statement

An interdisciplinary team of Sandians provided essential and timely support to the Pantex Site-Wide Environmental Impact Statement (EIS), required periodically by DOE orders to enable continued operations. Sandia nuclear weapon safety experts teamed with reactor accident experts and explosives modelers to assess the potential for offsite radioactive releases associated with postulated weapon disassembly accidents that could endanger the public. In addition, nuclear weapon safety experts provided essential data to estimate the possibility of aircraft crashes at the site. Resolution of these issues was essential to the filing of the EIS.

TECHNOLOGY PARTNERSHIPS & COMMERCIAL-IZATION



VCSEL—Sandia-developed vertical-cavity surface-emitting lasers were called a key technology of the 21st century for the optoelectronics industry.

Vertical-Cavity Surface-Emitting Lasers

Vertical-cavity surface-emitting lasers (VCSELs) were recently recognized as a key technology for the 21st century by the Optoelectronics Industry Development Association. The crystal structure of VCSELs is "grown" on top of a semiconductor substrate using a state-of-the-art procedure that deposits materials with atomic-layer precision. The growth is controlled to produce a multilayered bottom region of material that acts like a very-high-performance mirror, a middle region that emits light when electrically charged, and a top region of mirror-like material. Sandia has made great strides in this area with the successful transfer of visible VCSEL technology to Xerox Corporation and Honeywell Corporation under a program sponsored by the Advanced Research Project Agency. Sandia's contributions include advancing the performance of visible VCSELs to meet laser printing and plastic-fiber data-link system specifications, as well as transferring to industrial partners the techniques for VCSEL growth, for heterostructure design (design of the multilayered laser structure), and for fabrication of the wafers into working laser devices.

Advanced Repair Technique for Commercial Aircraft

An advanced technique for repairing commercial aircraft was developed and validated by a Sandia-managed project funded by the Federal Aviation Administration that teamed Sandia, Lockheed Martin, Delta Airlines, and Textron. The technique centers around the use of a bonded composite doubler—a fiber-reinforced, synthetic material that bonds to an airplane to create a very strong repair. This technique can replace conventional, riveted metallic patches. The primary advantage of this new technique is that it eliminates rivet holes, which can create stress risers and potential crack sites. The bonded composite doubler also provides a high strength-to-weight ratio, corrosion resistance, improved aerodynamics, and time savings in installation. Another big advantage is

that the bonded composite doubler is flexible until it is cured by applying heat and pressure. Thus it can be bent around complex shapes such as the leading edge of a wing. Sandia also produced inspection procedures, included in industry-approved directives, that allow the use of bonded composite doublers on commercial aircraft. The first FAA-approved composite doubler was recently installed on a commercial aircraft. The doubler was applied to the door corner of an L-1011 aircraft, which is currently operating in the Delta Air Lines fleet.

On-Line Process Control of Aluminum Manufacturing

In partnership with the Aluminum Company of America (Alcoa), Sandia's Basic Energy Sciences Materials Program has developed a computer code that can predict the precipitate particles in aluminum alloys at the microscopic level, based on the alloy's chemical composition and heating history. These precipitates give strength to the alloy—aluminum without them would be too soft. No other predictive tool of this kind exists. To ensure that the particles are present in the desired concentrations and shapes after the complex manufacturing sequence, a sample piece is cut and analyzed under the microscope with X-ray diffraction. If it does not come out right, there is no way to make corrections. The new code will provide on-line process control, giving mill operators the opportunity to change heating processes or temperatures to modify the alloy while it is being manufactured. Eventually, the aluminum manufacturing process will become highly computerized and rely heavily on sensors. When this happens, the new code will be very important for controlling temperatures and processes for optimal production. The basic code is generic, but the database that Sandia has developed around the code is specific to aluminum alloys. Besides being a valuable commercial tool, the code is important to Sandia for assessing components in weapon systems that are exposed to unusual environments. The code will help researchers determine how the strength and mechanical properties of these components change with time.

Electronic Commerce System at U.S.-Mexican Ports of Entry

Sandia-designed software, which uses the Internet, will serve as an electronic commerce system to expedite document flow and commercial vehicle traffic for shipments passing through U.S.-Mexican ports of entry. Federal inspection agencies, customs brokers, transportation providers, and manufacturing shippers will benefit from this secure information system, which may replace the paper-intensive and error-prone process currently in use. Border crossing process maps, which consist of flow charts of cross-border material handling and information processes, are being developed as part of the overall project, along with hardware (a container monitoring and tracking system) that travels with the freight to remotely observe the shipment in transit. This monitoring and tracking system reports the location of the shipment to a commercial satellite system, which forwards data to the Internet, where the electronic commerce software can process and display the information for users. The status of the shipment, such as its temperature or the times and locations that the trailer/container door was opened, can also be detected by sensors and relayed to the satellite. The project is sponsored by the New Mexico State Highway and Transportation Department and the Federal Highway Administration and is part of Sandia's Advanced Technologies for International and Intermodal Ports of Entry project.

Sensor Devices for the Steelmaking Process

Sandia's steel sensors team completed the design, construction, and field testing of optical sensors for oxygen-blown steelmaking processes. When incorporated into industrial process-control systems, the sensors will permit the U.S. steel industry to reduce the time needed for each "heat," reduce oxygen consumption, and improve the efficiency and reliability of the steelmaking process. Sandia's sensors include:

- Fiber-optic-coupled sensors—packaged into 70-foot-long oxygen lances that blast powerful jets of oxygen into the molten steel bath—for real-time monitoring of the temperature of the melt and the slag in basic oxygen furnaces and electric arc furnaces.
- Optical range-finding sensors to monitor the position of the oxygen lance relative to the molten steel surface and to monitor wear and tear of the ceramic lining of the furnace after the molten steel is poured.
- Tunable-diode-laser sensors that operate at the mouth of the furnace to monitor the ratio of carbon monoxide to carbon dioxide, measure the presence of particulates in the gas above the molten steel, and measure the gas temperature.

The commercialization of these sensors is now under way with the American Iron and Steel Institute.

Improvements to San Francisco's Bay Area Rapid Transit (BART) System

An existing Cooperative Research and Development Agreement between Sandia and San Francisco's Bay Area Rapid Transit (BART) district was expanded to include two tasks associated with BART's Advanced Automatic Train Control System. The two new tasks include conducting a safety analysis and review at the software and system levels, and developing enhanced-control algorithms to efficiently manage energy (and avoid severe voltage sags) without violating safety and schedule constraints. The baseline system, currently being developed and tested by BART and Hughes Aircraft with funding from the Advanced Research Project Agency, will improve system performance by allowing closer spacing of trains. The enhanced system will incorporate algorithms for energy management aimed at, for example, maintaining minimum train voltage, drawing energy from backup systems, coordinating accelerating and braking trains, and coasting to save energy.

BART—San Francisco's Bay Area Rapid Transit system

Sensor-Based Automated Sewing System

Sandia's robotics team delivered an automated sewing system—based on a unique, Sandia-developed sensor—to Textile/Clothing Technology Corporation (TC2) of Cary, N.C. This new sewing system uses capacitive sensors to detect fabric fed into a sewing machine. When the fabric is correctly positioned, it is clamped down. Sensors then help motors align the fabric as workers sew a complicated seam into the garment. The delivery of this automated system completes a two-year CRADA to transfer advanced Sandia capacitive sensor technology to the U.S. apparel industry. Before the automated system, workers had to manually feel for the edge of the material and frequently

SEW, SEW—A membor of Sandia's robotics team instructs a Textile/Clothing Technology Corporation (TC2) sewing operator in the use of an automated sewing system at TC2's manufacturing facility in Raleigh, N.C. The machine uses unique sensors developed at Sandia under the AMTEX CRADA.

suffered from cuts and wrist problems. The goal of the CRADA was to use advanced sensors to automate sewing processes, increase seam quality, and reduce operator fatigue. The automated system is expected to improve efficiency and decrease work-related injuries. Industry representatives believe that this technology will help make the U.S. garment industry more competitive.

Licensing Agreements between Sandia and Industry

1996 was a productive year for licensing agreements between Sandia and industry: Commercial licenses increased 300 percent to 101 agreements, involving more than 89 pieces of intellectual property. Licensing income approached $750,000, patent applications were steady at 102, and invention disclosures declined slightly to 214.
Cash coming into Sandia from industry partners totaled nearly $26.9 million: $12.4 million from Cooperative Research and Development Agreements that govern collaborative R&D activities between Sandia and industry; $13.4 million from Work for Others/Non-federal Entity Agreements sponsored by non-federal entities such as industry, state and local governments, and foreign governments; $719,000 from User Facility Agreements with partners who use Sandia's unique facilities for research, testing, and development; and $172,000 from Technical Assistance Agreements provided to businesses.

Patents and Licensing Accomplishments

Sandia's Patents & Licensing Department achieved the following milestones during 1996:

- Processed more than 200 new invention disclosures.
- Filed 102 patent applications with the U.S. Patent and Trademark Office.
- Issued 46 new U.S. patents.
- Drafted and executed more than 100 commercial license agreements in support of Sandia's Technology Partnerships & Commercialization Center and the California Site Development Center, resulting in more than $700,000 in royalty income.